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MIGRATION OF HAZARDOUS SUBSTANCES THROUGH SOIL

PART IV

DEVELOPMENT OF A SERIAL BATCH EXTRACTION METHOD AND APPLICATION TO THE ACCELERATED TESTING OF SEVEN INDUSTRIAL WASTES

by

Duane E. Long
Martin J. Houle
Donald C. Weatherhead, Jr
Gordon K. Ricks

Chemical Laboratory Division
U.S. Army Dugway Proving Ground
Dugway, Utah 84022-5000

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Dr. Michael Roulier, EPA Project Officer

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The initial objective of this work was to measure the leachability of selected wastes and determine the attenuation characteristics of certain soils. But, because the distribution of an ion between a waste leachate and a soil depends upon the composition of the leachate and the prior history of the soil (both of which change as leaching progresses and as more soil is penetrated), it was necessary to develop an experimental approach capable of simulating this dynamically-changing situation. Column studies were too time-consuming and inflexible.

Successive extracts of a waste were used to challenge a sequence of three soil batches. The soil batches were graded in size to allow analyzing samples of the extracts between each step. The extraction volumes were related to

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Samples of wastes were collected from the following industries: zinc-carbon battery manufacturing, titanium dioxide pigment production, hydrofluoric acid manufacturing, white phosphorus production, oil re-refining, and two from zinc secondary-refining (cinders and scrubber-waste). After analyzing these wastes to determine the content of potentially hazardous inorganic ions, they were examined by the graded serial batch extraction procedure. Water extracts of these wastes were applied to Chalmers, Davidson, and Nicholson soils. The analysis of the resulting solutions for pH, conductivity, and concentrations of specified hazardous ions before and after contact with these clay soils allowed calculating distribution coefficients (the slopes of adsorption isotherms), penetration factors, the fraction of each ion retained on the soils, the amount flushed off from a soil by the passage of a later extract, the yield of an ion per unit weight of waste, and the amount of an ion penetrating and retained by a unit weight of soil. The effect of soil-to-waste ratio on these measurements was also obtained. The limitations and applicability of empirical equations and prediction models is also discussed.

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This study was part of a major research program investigating the leachability of a number of industrial wastes and the migration of hazardous components through soil. The work was funded by the Environmental Protection Agency, Municipal Environmental Research Laboratory, Solid and Hazardous Waste Division, Cincinnati, Ohio 45268, under Interagency Agreement EPA-IAG-04-0443. This report covers experimental work done during the period July 1976 to February 1978.

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SECTION 1

INTRODUCTION

BACKGROUND

As concern increases about protecting the environment from the effects of improper and/or indiscriminate dumping of potentially hazardous wastes, regulations are promulgated regarding final disposal of these wastes. The intent of these regulations is to prevent incidents, such as contamination of ground or surface waters, that may adversely affect animal or plant life. However, a waste is not necessarily hazardous just because it contains toxic substances. It may be possible to dispose of certain types of these wastes with little or no pretreatment simply by placing them in landfills. Other types of waste, no doubt, will require either extensive treatment or storage in a specially designed disposal site. Before these judgments can be made, each type of waste must be characterized as to the amount and leachability of the toxic substances it contains.

The ability of a soil to retard the movement of chemical substances leached from a waste is one of the important factors in designing and selecting a disposal site for each type of waste. Unless the soil can adequately retard waste leachate movement or remove the toxic substances from the leachate, contamination of ground-water may result. The chemical and physical composition of a soil are the primary factors determining the soil's effectiveness for shielding ground-water from contamination. However, the composition of the waste and environmental factors such as annual precipitation, are also very important. These factors may be of equal or greater importance than the soil composition if a very soluble waste containing large quantities of toxic substances is improperly disposed of.

Before the movement of contaminants through soil can be evaluated in quantitative terms, it is necessary to have at least a qualitative picture of the important aspects of the process. As a waste is leached by precipitation and other surface water, components in it are depleted. This generally will cause each succeeding volume of extract to have a different composition. The most soluble chemicals will leach out first, so the initial washings usually contain the highest concentrations of salts as shown in Figure 1. Besides being challenged by a changing solution, the soil's ion-removal characteristics continually change with time as the soil becomes conditioned and loaded by the passage of waste extracts. Since each portion of waste is changed by passage through a segment (layer) of soil, the conditioning each succeeding segment of soil receives is different and each segment therefore may remove different proportions of the various ions present in the waste

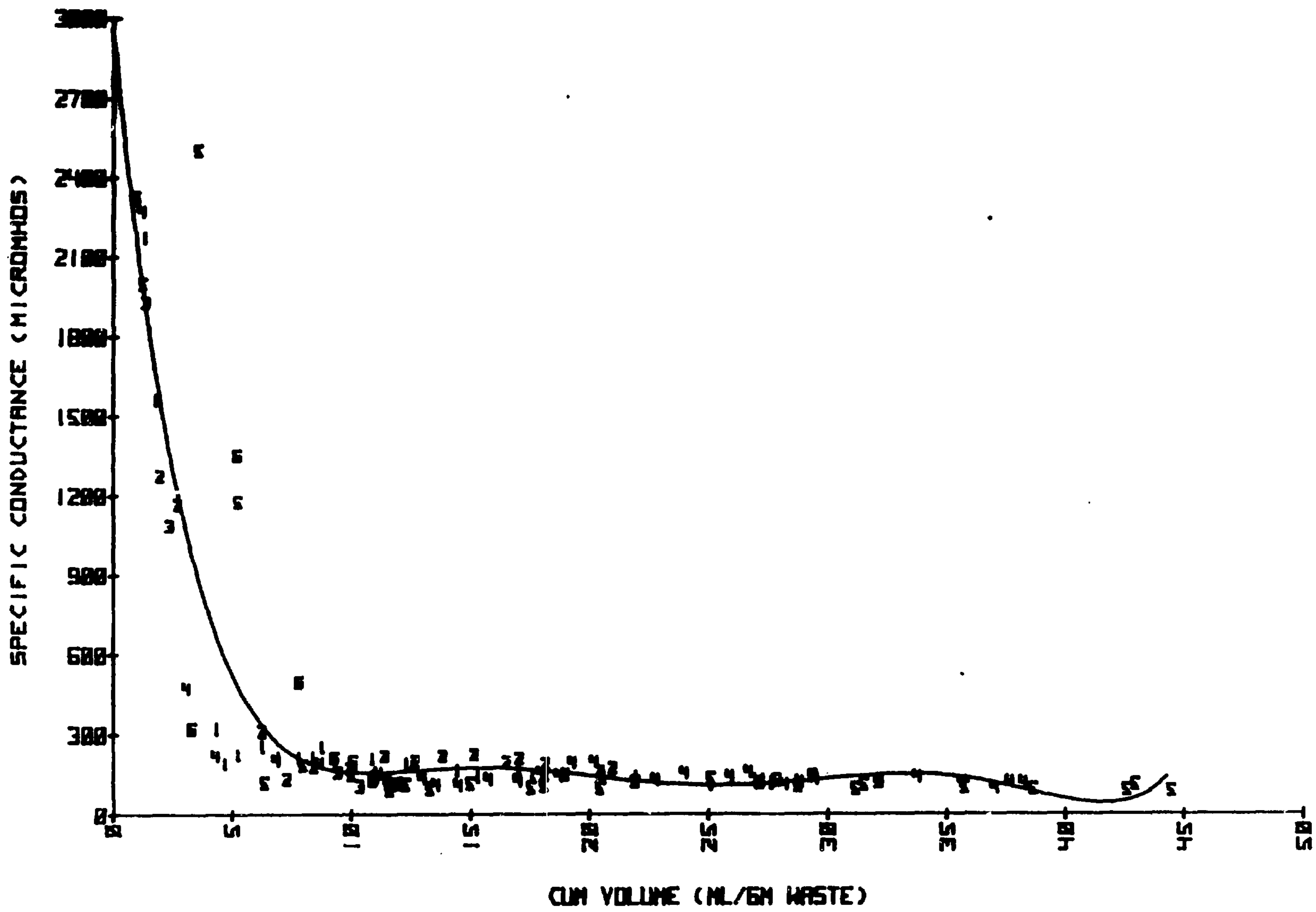

FIGURE 1. CONDUCTANCE OF SOLUTION LEACHED FROM PAINT WASTE BY WATER.[1]

extract. So although the soil segments start out the same, in effect they become different soils due to the passage of the different waste extracts.

The soil may remove ions from the waste, but the waste extract can also displace ions from the soil. This release of ions originally present in the soil can shift with quantity and type of ions present in the extract. The soil may also give up ions that it previously had removed from the extract, because the soil's characteristics can change due to the passage of the waste-extract solution which, as mentioned above, changes with depth and with extent of leaching.

OBJECTIVES

The initial objective of this work was to measure the leachability of selected wastes and determine the attenuation characteristics of certain soils. But to be able to correctly evaluate this dynamically changing situation, it was necessary to design an experimental approach that takes into account the changes in the nature of the soil and the changes in the total composition of the waste extract as leaching progresses. For future applications, this laboratory procedure should also be rapid and versatile to facilitate examining the effect of other variables of potential importance in a field situation. Such a procedure would be usable for research intended to improve land disposal technology and to provide input data for prediction equations. It would also allow rapidly measuring the leachability of hazardous materials from a waste and determining the effectiveness of soils underlying a potential disposal site.

EXPERIMENTAL PROCEDURE

A graded serial batch extraction procedure was developed for rapidly determining the leachability of wastes and the attenuation characteristics of soils. In this experimental approach, a weighed amount of waste is extracted by a specified amount of water, then, after remaining in contact long enough to equilibrate, the waste extract is filtered, a sample is taken for analysis, and a measured volume of the extract is placed on a certain weight of soil. This soil slurry is equilibrated, filtered, a sample of the extract is taken for analysis, and a volume of the remaining extract is placed on a lesser amount of soil. (This is to allow maintaining a constant liquid-to-solid ratio in spite of having taken a sample.) The process is again repeated with a third even smaller batch of soil. Meanwhile, the original extracted waste is treated with a second, larger, volume of water and this extract is passed down through the same three batches of soil, in succession. This process is repeated until the desired number of extractions have been performed. Depending upon the rate of movement of the liquid front at the field site of interest, the series of seven extractions utilized for this work were the equivalent of from two months (at 10^{-4} cm/sec liquid front velocity in the pores) to 17 years (at 10^{-6} cm/sec pore water velocity) of leaching.

Samples of wastes were collected from the following industries: zinc-carbon battery manufacturing, titanium dioxide pigment production, hydrofluoric

acid manufacturing, white phosphorus production, oil re-refining, and two from zinc secondary-refining (cinders and scrubber-waste). After analyzing these wastes to determine the content of potentially hazardous inorganic ions, they were examined by the graded serial batch extraction procedure. Water extracts of these wastes were applied to Chalmers, Davidson, and Nicholson soils. The analysis of the resulting solutions for pH, conductivity, and concentrations of specified hazardous ions before and after contact with the soils allowed calculating distribution coefficients (the slopes of adsorption isotherms), penetration factors (the reciprocal of attenuation factor), the fraction of each ion retained on the soils, the amount flushed off from a soil by the passage of a later extract, the yield of an ion per unit weight of waste, and the amount of an ion penetrating and retained by a unit weight of soil (expressed in micrograms of the ion per gram of waste or soil, which is numerically equivalent to grams per metric ton of approximately 2200 lbs.) The effect of soil-to-waste ratio on these measurements was also obtained. Although characteristics of specific wastes and soils were determined, the results cannot be considered as representative of each type of waste studied, because only a single plant was sampled in each industry.

SECTION 2

CONCLUSIONS

POLLUTION PREDICTION TECHNIQUES

1. The current state of knowledge is not sufficient to allow formulating a workable prediction model that includes all of the variables controlling ion movement in soils. The most reliable means for predicting the effects of a waste on adjacent or underlying waters at a proposed location is to derive empirical equations from site-specific experiments which simulate the important aspects of the field situation.

2. The concentration of ions in the leachate from a waste changes over time because the most soluble components of the waste are removed first and the less soluble are released more slowly and over a longer period of time. Because of this leaching behavior, and the fact that retention by soil depends upon both the current solution composition and the soil's history of exposure, simplified solutions of constant composition should not be used to simulate field conditions.

3. The retention of chemical species by a soil depends upon mechanisms other than just adsorption and is affected by numerous variables besides temperature, so the usual contaminant-soil adsorption isotherms are too limited to be useful for determining the effects of waste disposal upon soil. Because the conditions for retention vary continually as a function of the leaching of the waste and of the depth and pre-conditioning of the soil, these factors must be included in the design of the experiments.

4. To assess the suitability of a site for disposing of a given waste, the leaching behavior of the waste can be characterized and the ability of the underlying soils to remove a chemical species from the waste leachate can be more conveniently and rapidly evaluated with properly designed serial batch extractions than with other techniques such as column studies. The characteristics of the proposed graded serial batch extraction technique also allows readily conducting the experiments required to evaluate alternative site management procedures in the usual situation where more than one waste is to be placed in a site and where one kind of soil underlies another.

ZINC-CARBON BATTERIES

1. The initial concentrations of cadmium, lead, mercury, and zinc in the water extracts of broken zinc-carbon batteries were low to moderately high compared to the safe drinking water standards (listed in Table 14) and the concentrations decreased further as leaching progressed.

2. After contact with clay soils (Chalmers, Davidson and Nicholson soils), the waste leachate contained very low concentrations of these metals.

TITANIUM DIOXIDE PIGMENT WASTE

1. Water extracts of this waste contained low to very low concentrations of chromium, lead and titanium. The compounds containing these metals apparently were very insoluble, as only a few hundreths of a percent dissolved during the entire series of seven extractions.

2. After contact with clay soils, the waste leachate contained very low concentrations of these metals.

HYDROFLUORIC ACID WASTE

1. The waste sample was taken prior to the final neutralization in the waste treatment process because some manufacturing plants do not include this step.

2. Water extracts were highly acidic and contained high concentrations of fluoride. The seven extractions removed 56 percent of the total fluorine in the waste.

3. Clay soils were initially very effective in removing fluoride from the waste leachate, but by the fourth extraction they were releasing substantial amounts of fluoride previously retained.

4. Land disposal of acidic wastes containing fluorine will require special attention because of the potential for fluoride movement in soils.

WHITE PHOSPHORUS WASTE

1. The water extracts were of high pH, although the concentrations of fluorides and phosphorus-containing compounds were very low.

2. Only a few tenths of a percent of the available fluorine and phosphorus were removed in the seven extractions, so the waste appeared to be a long-term source of fluoride ion.

3. After continued exposure to the strongly basic leachate, the soils lost their ability to reduce the pH and they also started to release previously-retained fluoride and phosphorus.

ZINC SECONDARY-REFINING CINDERS

1. These cinders had been laying in an open dumping area, so were already partly leached.

2. The water extracts yielded low or very low concentrations of cadmium, lead, nickel, and zinc.

3. The sample tested was quite insoluble and only a few tenths of a percent of lead, nickel, and zinc dissolved, and less than three percent of the cadmium was removed by the seven extractions.

4. The effluents from the soils contained very low concentrations of these metals, although previously-retained cadmium was being released in the later extractions.

ZINC SECONDARY-REFINING SLUDGE

1. Water extracts of the sludge from this industry produced a leachate with a very high initial cadmium concentration which then dropped to a low level. The clay soils passed only low levels of this metal, but began to give up cadmium previously retained, indicating the possibility of poor performance upon further exposure to this waste.

2. Lead was retained very well by all three clay soils and only low concentrations penetrated them. The waste appeared to be a long-term source of lead; the concentration of lead was moderately high in the waste extract throughout the period of leaching, and although only 2.2 percent of the lead was extracted during these tests, the waste is about 6.8 percent lead.

3. Nickel was present only in very low concentrations and after passage through clay soils dropped below the detection limit.

4. The zinc salts were sufficiently soluble at first to give a solution of moderate zinc concentration, but it dropped to a low concentration by the seventh extraction. Although only three percent of the zinc dissolved in this time, potentially leaving a long-term source (this waste was 38 percent zinc), the concentration should be very low unless influenced by external factors. The clay soils further reduced the zinc concentration, with Nicholson and Chalmers soils retaining about 80 percent, and Davidson soil 50 percent of the cumulative challenge.

OIL RE-REFINING WASTE

1. Extremely low concentrations of beryllium were leached by water from this organic waste but the highly acidic solutions were powerful displacers of beryllium from the soils.

2. Boron appeared at moderately low concentration in the initial water extracts. The ability of clay soil to remove boron from solution dropped rapidly and the soils soon gave up previously-retained boron.

3. The initial extracts contained moderate concentrations of cadmium. The soil effluents usually contained higher concentrations than the challenges, showing that cadmium was displaced from the soils by components of the highly-acidic extracts.

4. Chromium initially appeared at a moderate concentration, but the soil extracts were always higher than the challenge, showing that the composition of the extracts caused release of chromium from the soils.

5. Copper was eluted from the waste in very low concentrations, but considerably more copper was displaced from the soils than was present in the series of waste extracts.

6. Moderate concentrations of lead persisted in the waste extracts, and lead was released from the soils in many of the extractions.

7. Very low concentrations of nickel were found in the waste extracts, but these solutions displaced considerable amounts of nickel from the soils.

8. Very, very low concentrations of titanium leached out of this waste. The acidic extracts displaced considerable titanium from the soils.

9. Moderate concentrations of zinc were found in the initial extractions and although this element was retained by clay soil from the first extract, it generally was released by subsequent extractions throughout the remainder of the series.

SECTION 3

RECOMMENDATIONS

1. The graded serial batch extraction technique should be used to conduct experiments designed to examine the following aspects of waste disposal:

The leaching of ions from combinations of wastes or wastes deposited in sequence, and the net retention by soil of ions from these leachates.

The leaching and retention of ions when extractants other than distilled or deionized water are used — e.g., municipal landfill leachate or simulated acid rain.

The long term retention of ions by soil after overlying wastes have ceased releasing ions. (Appendices C and D show preliminary studies on the flushing by water of soils previously exposed to wastes, and the effects of placing new waste on already leached wastes and soils.)

2. Because the distribution of ions between the soil and the solution passing through it varies with the number of soil batches (which simulate increased soil depth), work should be conducted with greater numbers of batches to examine the ability to extrapolate to even greater depths of soil in the field.

3. Results from this procedure should be compared with carefully-planned field trials. Measurements should be made of the effects of those factors that significantly affect the accuracy of extrapolation to a field situation.

4. Because the first water extract of a waste removes the most soluble components and commonly contains the greatest amounts of toxic ions, the feasibility of extracting waste solids once or twice with water (perhaps then drying them to render hydrated species less soluble) and treating washings separately should be examined as a way of greatly reducing the hazard from disposal on land.

5. The serial batch extraction procedure can be used to study the effectiveness of various fixation processes for industrial wastes. The accelerated testing capability it provides should allow rapidly estimating the long-term ability of many kinds of processes to retard solubility.

SECTION 4

METHODS AND MATERIALS

WASTE AND SOIL EXTRACTION METHOD

A sequence of seven extracts was made from each waste. Ordinarily a sample of waste was dried to determine moisture content, then sufficient undried sample was weighed to give 300 grams dry weight. (Drying the sample could affect hydrated species and drastically reduce the solubility.) If the waste had supernatant water, the volume of the water was considered as part or all of the first extract. Appropriate volumes of water were added for each extraction to produce the liquid-to-solid ratio given in the second column of Table 1. The sample bottle was shaken gently 4 or 5 times daily (continual mechanical shaking was not used because of concern that it might abrade the waste agglomerates, making them more susceptible to extraction). The time required to reach equilibrium was determined by periodically withdrawing an aliquot for analysis; 24 hours is adequate for most wastes of small particle size. However, longer extraction was required for some wastes. At the end of the extraction period, the mixture was filtered under vacuum using a hardened filter paper (such as Whatman 54) in a Buchner funnel. An aliquot of approximately 20 milliliters of the filtrate was withdrawn for analysis of metals, etc. and filtered through a 0.5 μ Millipore filter to remove fine particles which might have by-passed the filter paper and could dissolve when the sample was acidified (after measuring conductance pH, and fluoride ion, one percent concentrated nitric acid was added to the filtrate to inhibit precipitation while standing). The solid waste residue was transferred back to the jar and mixed with the volume of water specified for the next batch. The flow-chart of Figure 2 outlines the sequence of operations.

TABLE 1. SPECIFICATIONS FOR SERIAL BATCH EXTRACTIONS [2]

Extraction Number	Water Added (ml/g)	Volume of Water (ml) Extracting 300 g Waste	Volume of Filtrate Onto a Soil (ml) I 60 g Soil	II 30 g Soil	III 15 g Soil
1	2	600	120	60	30
2	3	900	180	90	45
3	6	1,800	360	180	90
4	12	3,600	720	360	180
5	24	7,200	1,440	720	360
6	48	14,400	2,880	1,440	720
7	96	28,800	5,760	2,880	1,440

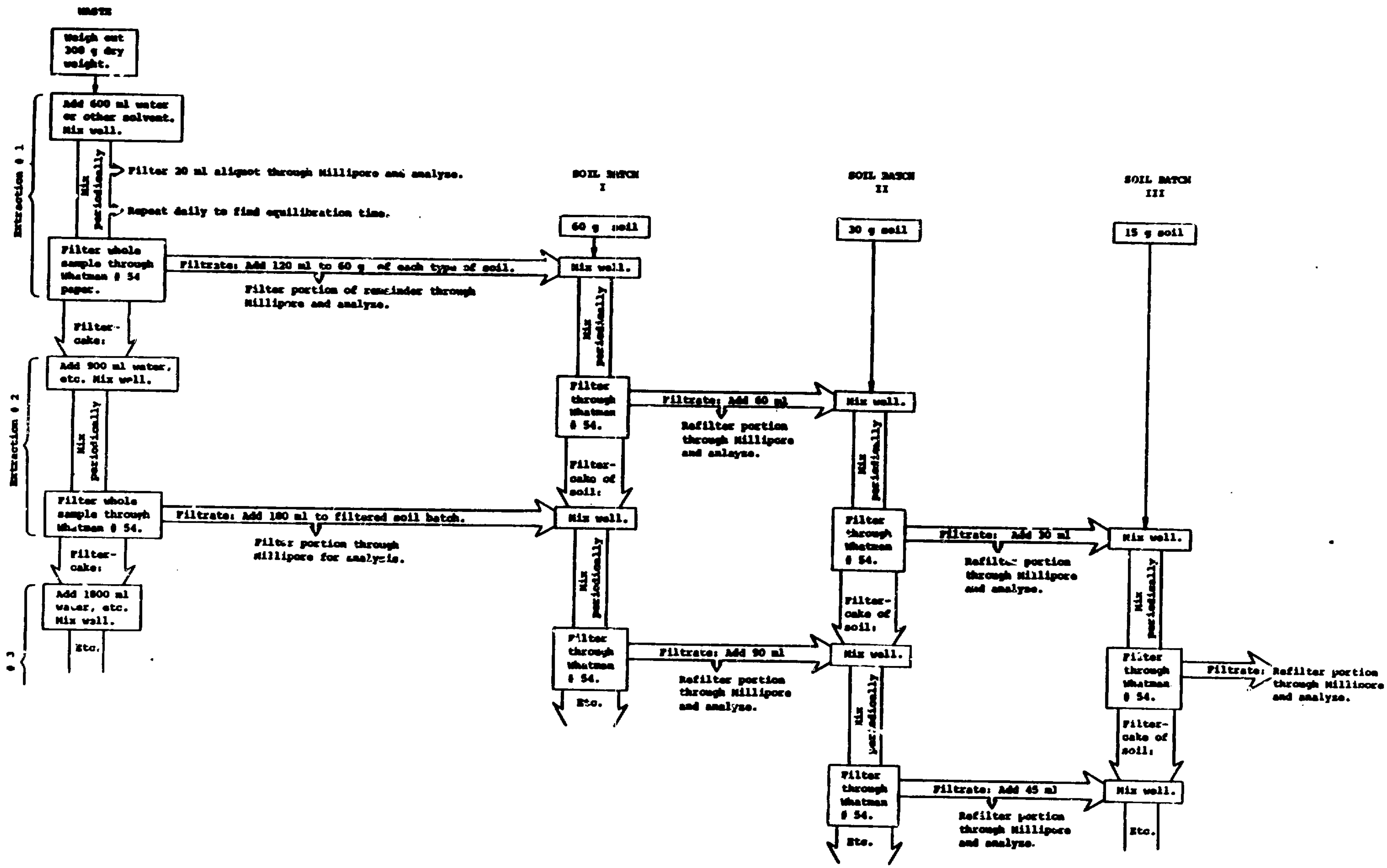

FIGURE 2. FLOW CHART FOR GRADED SERIAL BATCH EXTRACTIONS.

In the procedure detailed here the liquid-to-solid ratio was continually increased (Figure 3) to further accelerate the testing—the volume of each extraction after the second one was made double the one before, which redoubles the time represented by that extract (see discussion in Section 5). (With some wastes, adequate results may be obtainable by using very large volumes right from the first, or, one or two extractions using small liquid-to-solid ratios, followed by a very large one as shown in Figure 4. However, this would have to be checked for each kind of waste by comparison with the more conservative series of extractions utilized in Table 1. Such a procedure would allow rapid simulation of long leaching periods and could be useful in the routine monitoring of variations in waste composition and leachability.) (3)

The filtrate resulting from each sequential extraction of the waste was mixed with the first of three batches of each kind of soil. The weights of soil used were 60, 30, 15 grams, representing section I, II, and III, respectively. This gradation in weight allows taking an aliquot of the extract for analysis and having enough extract left over to challenge the next soil batch at the same liquid-to-solid ratio. Extracting 300 grams of waste yields sufficient solution to challenge three different kinds of soil in experiments set up with the proportions stated in Table 1.

Although the soil equilibrates in six hours or less (4), each solution was kept in contact with the batch of soil before filtration for the same length of time as used to extract the waste. This was to keep the samples progressing smoothly without gaps in the series. After filtering the soil extract, an aliquot was refiltered through a Millipore filter and saved for analysis. The appropriate volume of the remaining filtrate was added to the next batch of soil. The soil exposed to the first waste extract was recovered and mixed with the second waste extract in the series. This was repeated until the waste had been extracted seven times and each waste extract had progressed through all three soil batches. (An eighth extract could have been made to further increase the equivalent leaching time.) This procedure was run in duplicate.

METHODS OF ANALYSIS

Conductance and pH

The pH and conductance of each waste and soil sample were measured using the standard procedure specified in, "Manual of Methods for Chemical Analysis of Water and Wastes". (5)

Fluoride Content

Dissolved fluoride was determined using the fluoride ion activity electrode method (6). Total fluoride content of the wastes was measured using the Bellack distillation method (7), followed by the fluoride electrode method.

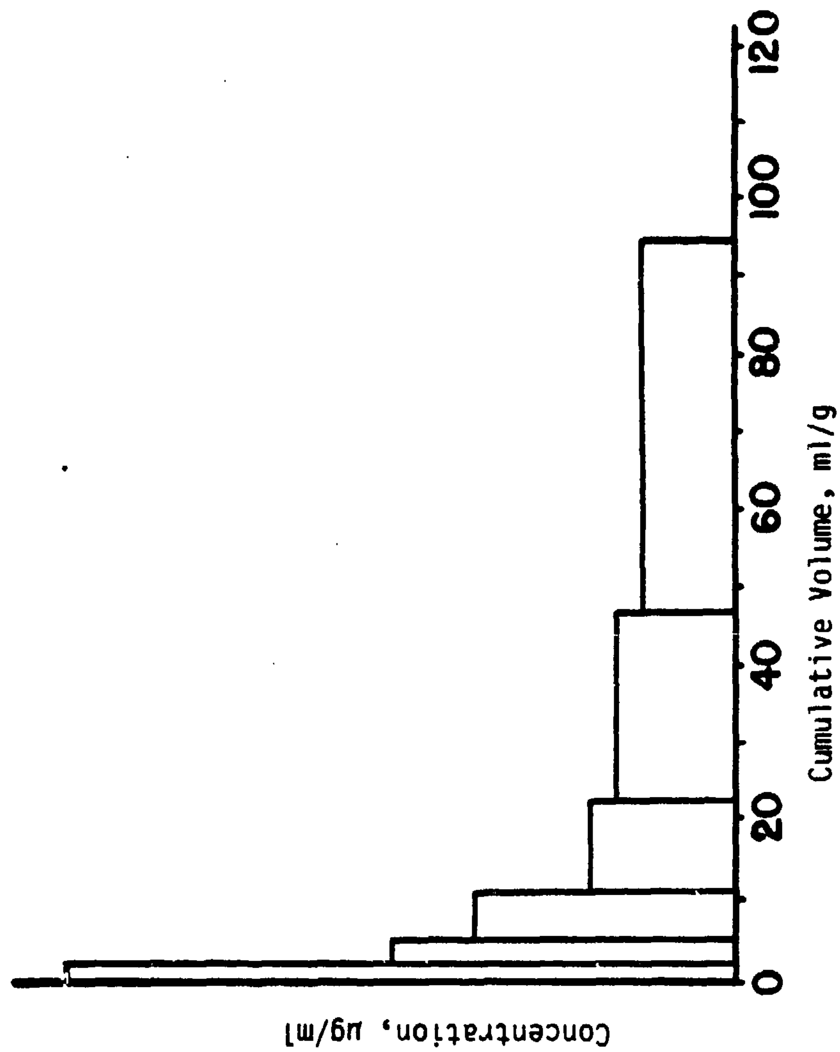

FIGURE 3. GRADED SERIAL EXTRACTIONS

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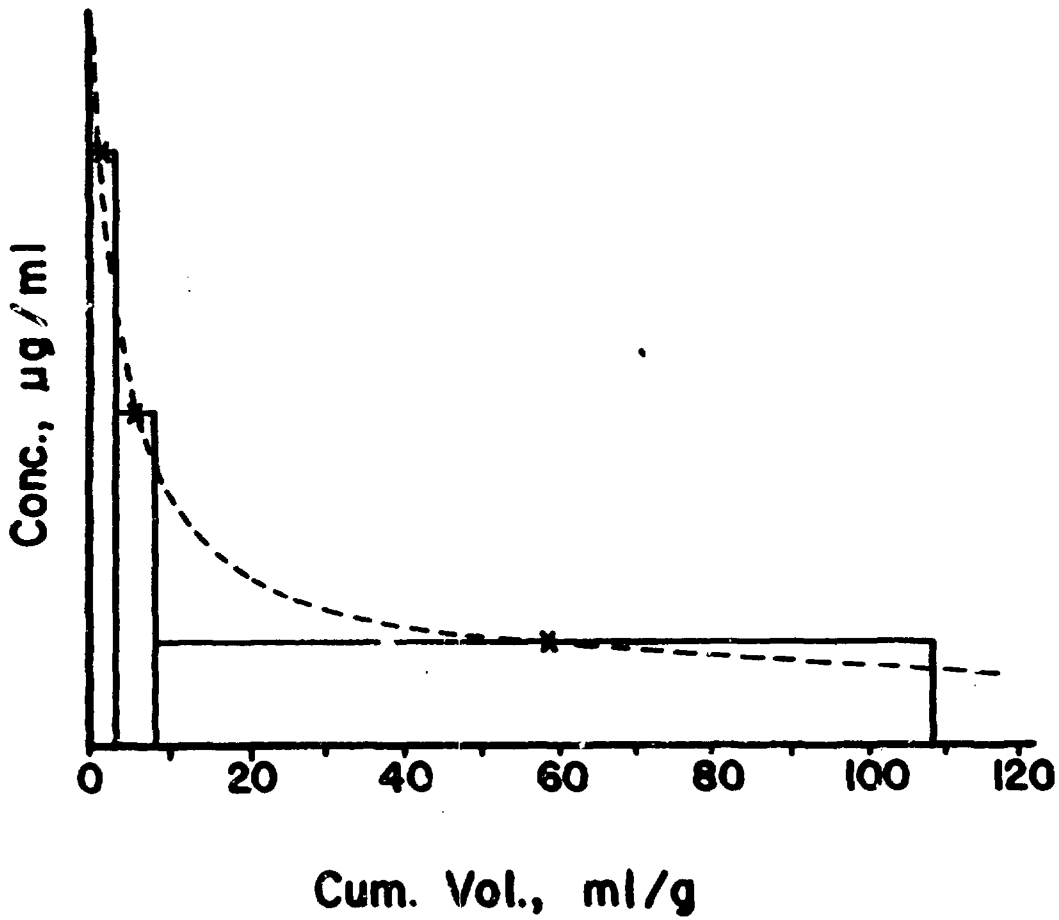

FIGURE 4. MAKING A RAPID ESTIMATE BY EXTRACTING WITH 3,5, AND 100 MILLITERS PER GRAM.

Phosphorus and Metal Content

Digestion of Wastes and Soils--

In order to determine the initial phosphorus and metal content of the wastes and soils, they were subjected to an aqua-regia digestion. One gram ± one milligram of dried waste or soil was weighed into a 400 ml beaker. Fifteen milliliters concentrated hydrochloric and five milliliters concentrated nitric acid was added to each sample. The samples were covered with watch glasses, placed on a hot plate at low heat, and evaporated (digested) to incipient dryness, taking care to prevent boiling-over or splattering of the digestion mixture. The samples were removed from the hot plate and allowed to cool for five minutes. The watch glasses and the sides of the beakers were washed down with distilled water. The acidity was adjusted by adding two milliliters concentrated nitric acid and bringing the volume in the beaker to 15 to 20 milliliters with distilled water. The samples were placed back on the hot plate, left uncovered, and brought to a low boil. The samples were then removed and allowed to cool for 15 minutes. They next were filtered through Whatman No. 54 filter paper into 50 milliliter volumetric flasks. The residue in the beakers was washed 5 to 7 times with small portions of distilled water, letting the washings pass through the filter between washings. The volumetric flasks were then filled to volume. A reagent blank was treated in the same manner.

Quantitative Analysis--

Mercury in undigested wastes and soils, and in the acidified batch extraction samples were measured using a Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer (AAS) equipped with the Perkin-Elmer Model 56 strip chart recorder and a Perkin-Elmer Flameless Mercury Analysis System. The detection limit was 0.02 micrograms mercury in 100 ml. The following operational parameters were used:

Wavelength - 253.7 nm;
Slit Setting - 4 (0.7 nm);
Light Source - Perkin-Elmer hollow cathode lamp.

A stock standard solution of mercury was made by dissolving 1.080 grams of Mercury (II) oxide in a minimum amount of (1:1) hydrochloric acid:distilled water and diluted to one liter with distilled water. This equalled 1000 micrograms/milliliter mercury.

The other elements investigated in this study were measured using argon plasma emission spectrophotometry. This technique offers several advantages over the more conventional AAS technique. These are:

a. Increased sensitivity for certain elements due to higher excitation temperature (6000° K in the working region of the plasma versus 3000° K for AAS flame). An example of the effect of this temperature increase on various elements can be found in the boron and phosphorus analyses. Boron can be determined at concentrations as low as 0.1 microgram/milliliter by plasma arc versus 6.0 micrograms/milliliter by AAS. Phosphorus can be measured as low

as 0.5 micrograms/milliliter by plasma arc. This element can not be measured by AAS at reasonable concentrations.

b. The method does not require a separate source for each element. Instead, the flame excites the element, and the optics of the instrument separates the specific wavelengths of light for each metal. By using an array of photomultiplier tubes and a preselected wavelength cassette, the spectrophotometer can be operated in a multi-element mode. This permits measuring up to 20 elements simultaneously.

c. It requires only one gas: Nonflamable, nontoxic argon. This is a distinct safety advantage over AAS.

The argon plasma emission method does have certain limitations. Although it is possible to measure 20 elements simultaneously, it is difficult to prepare one standard containing the desired quantities of twenty elements without precipitating some elements. However, a standard was prepared which contained one microgram/milliliter of beryllium, cadmium, chromium, copper, lead, nickel, titanium, and zinc and 10 micrograms/milliliter boron and 100 micrograms/milliliter magnesium. Phosphorus was prepared in a separate standard at a concentration of 100 micrograms/milliliter. This multi-element standard was acidified with concentrated nitric acid to one percent. In addition, it was prepared with 2000 micrograms/milliliter lithium for the reason discussed below.

One problem with the argon plasma emission method is the effect of alkaline metals and earths (sodium, potassium, calcium, and magnesium) upon the analysis of chromium, lead, and zinc. The effect usually appears as a positive enhancement in the response from these elements and is read as erroneously high concentrations. Because relatively high concentrations of alkaline metals and earths were expected in some of the samples, it was imperative that effect upon the argon plasma emission method be eliminated. It has been reported that the enhancement can be suppressed through the addition of lithium to each sample. This was investigated using several concentrations of lithium. It was found that 2000 micrograms lithium/milliliter completely suppressed the effect of the alkaline metals and earths upon the chromium and zinc analyses and partially suppressed the effect upon the lead analysis. It was determined that the lead analysis enhancement was caused by magnesium, probably due to line spreading of a strong magnesium line at 2802 Angstroms or a weak intensity line at 2852 Angstroms. These two magnesium lines bracketed the analytical line for lead located at 2833 Angstroms. This is not the optimum emission line available for lead but potential emissions from other elements dictated selection of the 2833 Angstrom line if more severe interferences were to be avoided.

In order to analyze lead using the argon plasma emission spectrophotometer, a means of compensating for the magnesium enhancement was needed. A three-level factorial experiment was run to quantitate the effect of magnesium and the magnitude of interactions. A correction-equation was derived for the instrument by regression analysis so that by measuring the magnesium concentration and the apparent lead concentration, the actual lead concentration could be obtained. The reliability of this method was tested by

analyzing samples for magnesium and lead and applying the results to the correction equation. The samples were then analyzed by AAS. Comparison of the results from both methods showed good agreement.

The precision and sensitivity of the argon plasma emission method for the elements of interest was determined using the multi-element standards (except for phosphorus). The results are shown in Table 2. The lowest concentration of each element listed in this table is approximately the detection limit of the argon plasma emission equipment used in this study. However, the ability to quantitate at these levels was only fair. The higher concentration listed for each element was therefore considered the "operational" detection limit for the method. These multi-element standards were relatively simple compared with actual waste and soil extracts. They contained only the elements of interest plus acid and lithium, and not the diverse elements found in waste or soil samples. The sensitivity and precision of the method might deteriorate somewhat in complex samples, so the higher concentration was used as the detection limit in sample measurements and the data analysis.

TABLE 2. PRECISION AND SENSITIVITY OF THE ARGON PLASMA EMISSION METHOD

Element	Concentration (micrograms/milliliter)	Percent Coefficient of Variation
Be	0.005	0
	0.01	0
B	0.1	34
	0.5	3
Cd	0.01	17
	0.05	2
Cr	0.1	25
	0.05	2
Cu	0.01	18
	0.05	2
Ni	0.01	50
	0.05	2
P	0.1	45
	0.5	5
Pb	0.05	38
	0.1	13
Zn	0.01	27
	0.05	1

Check samples were furnished by the Environmental Protection Agency. The samples were prepared as specified and analyzed by the argon plasma emission method. The metals determined were beryllium, cadmium, chromium, copper, lead, nickel, and zinc. In one of the samples some of the elements were below the detection limits of the analytical method. The other elements were approximately at the detection limit. This required modifying the preparation of the "as received" sample in order to bring these elements within the limits of the method. Another one of the samples was slightly above the detection limits while the concentration of the elements in the third sample was considerably above the detection limits.

For the low concentration sample, the analyses ranged between 70 to 130 percent of the stated value, except for lead which was 160 percent of the stated value. The sample which contained the elements slightly above the detection limit gave results 87 to 106 percent of the stated value. The high concentration sample was analyzed as being 85 to 106 percent of the stated value.

The reliability of the argon plasma emission method was further investigated by adding beryllium, cadmium, chromium, copper, lead, nickel, and zinc to an extract from a flue-gas desulfurization waste in concentrations sufficient to give a 0.475 micrograms/milliliter above the *in situ* concentration of the elements in the waste. The results are shown in Table 3.

TABLE 3. RECOVERY OF ELEMENTS ADDED TO A WASTE EXTRACT

Element	Found	Percent Recovery
Pb	0.456	96
Cd	0.479	101
Cr	0.456	96
Cu	0.504	106
Ni	0.498	105
Pb	0.509	107
Zn	0.480	101

SOILS

The three soils used in this study were Chalmers soil from Indiana, Davidson soil from North Carolina, and Nicholson soil from Kentucky. These soils were collected from the B-horizon soil zone (30-100 centimeters in depth) at each location. These soils were selected because of differences in their physical and chemical properties and clay mineralogy. Table 4 shows that Chalmers and Nicholson soils have similar surface areas but significantly different cation exchange capacities. In addition, the clay mineral composition (< 2 micron separates) are much different. The Chalmers clay composition is largely montmorillonite, with small amounts of vermiculite, chlorite, and kaolinite. The Nicholson clay fraction is predominately vermiculite with only a trace of mica and kaolinite. In contrast, Davidson soil has a low surface area and cation exchange capacity. The clay is predominately kaolinite

but this soil contains a high percentage of hydrous oxides of iron. It has been shown that iron oxides play a major role in heavy and trace metal removal. (8)

TABLE 4. SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS USED IN THIS STUDY

Soil	Soil Paste pH	Cation Exchange Capacity (meq/100 g)	Surface Area (m^2/g)	Free Iron Oxides %	Texture: Sand %	Texture: Silt %	Texture: Clay %
Chalmers	6.6	26	125.6	3.1	7	58	35
Davidson	6.2	9	51.3	17.0	19	20	61
Nicholson	5.0	>37	>120.5	5.6	9	31	60

Samples of the three soils were subjected to aqua-regia digestion. The digestates were analyzed for the elements of interest using argon plasma emission spectrophotometry (except for fluoride, which was determined using a distillation and ion selective electrode method). These analyses were performed to obtain the amount of each element available for extraction and/or leaching from the soils in addition to that introduced by the waste. The results are shown in Table 5 expressed as microgram element/gram of soil.

WASTE SAMPLES

Seven industrial wastes were used in this study. They were characterzied as to their content of the elements of interest. Each waste will be discussed separately.

Zinc-Carbon Battery Waste

This waste consists of broken-open reject Lelanché (zinc-carbon) batteries. Approximately one percent of the batteries produced are rejected. Cadmium, mercury, lead, and zinc were the metals of interest in this waste. Table 6 gives an "industry average" for waste battery composition, (9) but proprietary differences in formulation exist between manufacturers and battery types.

TABLE 5. ELEMENTAL ANALYSIS OF SOILS

Soil	Element (microgram/gram) As	Be	B	Cd	Cr	Cu	F	Mg*	Ni	Pb	Ti	Zn
Chalmers	14.5	2.05	15.5	0.50	28.0	21.3	810.	1310.	24.6	111.	104.	62.0
Davidson	28.2	3.05	28.5	1.45	36.5	74.8	228.	915.	14.8	148.	1265	53.5
Nicholson	18 2	3.25	18.9	0.50	3.0	42.2	1560.	4970.	24.4	114.	118.	74.8

*Magnesium was determined for correcting the lead results.

TABLE 6. COMPOSITION OF ZINC-CARBON BATTERY WASTE (10)

Element	Concentration (microgram/gram)
Mercury	7.3
Zinc	3,800.
Zinc Chloride	248.
Manganese Dioxide	615.
Cadmium	0.27
Lead	0.31

Titanium Dioxide Pigment Production Waste

The waste from this industry results from equipment cleanup and the washing and drying of titanium dioxide pigment produced using the chlorine process. (10) In this process, rutile ore or beneficiated ilmenite is reacted with gaseous chlorine in the presence of coke to produce liquid titanium tetrachloride. This liquid is purified by distillation and oxidized in a flame to titanium dioxide which condenses as a fume. The pigment is washed and filtered. The water from these process steps is treated with alkali to increase the pH, thereby promoting precipitation of the metals from solution. The solids are separated from the water by filtration and trucked to a commercial disposal site. The sample used in this study was collected at the filter. The metals of interest were beryllium, cadmium, chromium, copper, lead, nickel, titanium, and zinc.

To establish the amount of each metal of interest present in the waste, a one gram portion of the waste (dry weight) was digested with aqua-regia, filtered and diluted. The metals listed above and boron, magnesium, and iron were analyzed for using argon plasma emission spectrophotometry. The results are shown in Table 7, expressed as microgram/gram of waste. This provides an estimate of the total weight of each element potentially available for leaching from the waste.

TABLE 7. ANALYSIS OF SELECTED ELEMENTS IN TITANIUM DIOXIDE PIGMENT WASTE

Element	Concentration (microgram/gram)
Beryllium	25.
Boron	590.
Cadmium	113.
Chromium	3,240.
Copper	84.
Iron	92,200.
Lead	270.
Magnesium*	7,650.
Nickel	270.
Titanium	34,300.
Zinc	430.

*Magnesium was measured in order to correct the lead result obtained by argon plasma emission spectrophotometry.

Hydrofluoric Acid Production Waste

This waste results from treating fluorspar with concentrated sulfuric acid to produce hydrofluoric acid. The residue is primarily calcium sulfate and a small amount of calcium fluoride. The dry residue is strongly acid. This residue is neutralized with lime and is pumped to a holding lagoon where it is de-watered and allowed to dry. The dried waste (gypsum) is pulverized and sized and trucked from the plant and used to stabilize road beds. The sample used in this evaluation was collected as a dry powder prior to the addition of lime. The waste was collected at this point in order to determine the effect of the waste when disposed of on land without neutralizing the excess acidity. (Some producers dispose of unneutralized waste.) The element of interest was fluorine. However, the concentrations of other elements were also determined so as to more thoroughly characterize the waste. As can be seen from the results presented in Table 8, their concentrations were quite low in comparison to fluorine.

TABLE 8. ANALYSIS OF SELECTED ELEMENTS IN HYDROFLUORIC ACID PRODUCTION WASTE

Element	Concentration (microgram/gram)
Beryllium	0.85
Boron	119.
Cadmium	9.2
Chromium	13.0
Copper	5.5
Fluorine	4,900.
Lead	66.2
Magnesium	272.
Nickel	9.4
Zinc	140.

White Phosphorus Production Waste

This waste originated from the production of elemental phosphorus by the electric furnace method whereby phosphorus is produced through the reduction of phosphate rock by coke using a silica flux. In this process, the raw phosphate rock is dried and then sized or agglomerated. The agglomerates are calcined in a rotary kiln. The gases emitted by the kiln contain phosphorus, fluorides, and fuel decomposition products. The gases are passed through a water scrubber and the resultant liquor is treated with lime to precipitate these compounds. The solid fraction of the waste is composed primarily of calcium fluoride, calcium phosphate, calcium sulfate and

unreacted lime. Slurries of this waste are highly alkaline (pH 12.7). Detailed discussion of the elemental phosphorus production is presented elsewhere (11).

The species of interest in this waste and in the waste leaching and soil migration studies were inorganic phosphorus (probably present as phosphates) and fluorides. In addition, beryllium, boron, cadmium, chromium, copper, lead, magnesium, nickel, and zinc were determined in the waste. The results of the analysis are shown in Table 9.

TABLE 9. ANALYSIS OF SELECTED ELEMENTS IN PHOSPHORUS PRODUCTION WASTE

Element	Concentration (microgram/gram)
Beryllium	2.97
Boron	4,180
Cadmium	12.9
Chromium	24.8
Copper	9.98
Fluorine	220,000.
Lead	230.
Magnesium	23,600.
Nickel	25.7
Phosphorus	14,400.
Zinc	63.2

Secondary Zinc Smelter Wastes

Two wastes were obtained from this industry. The first was cinders and ashes resulting from the smelting process before pollution control regulations were imposed. These cinders, rich in metals, had been deposited on the plant property. This resulted in a 1 to 10 foot layer of cinders covering 12 acres of the plant property. After pollution control regulations were instituted, a scrubber was installed on the stack. The sludge from the scrubber is disposed of among the cinders on the property. The scrubber sludge constitutes the second waste studied. The results of digesting and analyzing a sample of each waste are shown in Table 10.

TABLE 10. ANALYSES OF SELECTED ELEMENTS IN CINDERS AND SLUDGE WASTES FROM THE SECONDARY ZINC SMELTING INDUSTRY

Element	Concentration (microgram/gram)	
	Cinders	Sludge
Beryllium	3.92	0.82
Boron	130.	57.6
Cadmium	60.2	54.5
Chromium	36.2	14.8
Copper	3,070.	1,270.
Lead	12,500.	68,200.
Magnesium*	17.2	920.
Nickel	1890.	360.
Zinc	50,300.	383,000.

*Magnesium was measured in order to correct the lead result obtained by argon plasma emission spectrophotometry.

Oil Re-refining Waste

A waste was collected from the oil re-refining industry. The waste is generated by the re-refining of discarded crank case oil, transmission fluid, grease, etc. After the oil is dehydrated to remove water, alcohols, etc, it is heated with sulfuric acid. The acid solubilizes metals and other compounds that contaminate used oils. The acid is separated from the oil and discarded. This is the waste that was used in this study. The waste was a strongly acid, highly viscous, tarry material.

Triplicate samples of the waste were dissolved in aqua regia. Because of the high organic content of the waste, it had to be repeatedly mixed with fresh portions of aqua-regia, heated to incipient dryness, mixed with more aqua-regia and again heated to incipient dryness. The digestate was filtered, diluted to volume and analyzed by argon plasma emission spectrophotometry. The elements of interest were beryllium, boron, cadmium, chromium, copper, lead, nickel, phosphorus, titanium, and zinc. The results are shown in Table 11.

TABLE 11. ANALYSIS OF SELECTED ELEMENTS IN OIL RE-REFINING WASTE

Element	Concentration (microgram/gram)
Beryllium	Trace*
Boron	≈ 54.*
Cadmium	≈ 5.*
Chromium	36.3
Copper	58.7
Lead	2,330.
Nickel	≈ 2. *
Phosphorus	600.
Titanium	≈ 3. *
Zinc	190.

*The concentration in the digestate was in the region of the detection limit.

SECTION 5

DEVELOPMENT OF A RAPID LEACHING TEST

BACKGROUND

The major problem encountered in waste leaching studies is to duplicate the essential characteristics of the field conditions. That is, to include those variables active in the field that have a statistically significant effect upon the leaching of substances from a waste and/or the passage of these substances through soils, and to exclude or minimize variables that might be introduced by the experimental setup. This is the goal, and one can expect to fall short, but an investigator should be aware of how the experiments fell short so as to be able to specify the expected range of applicability of the findings and to qualify their ability to predict effects.

One obvious way of obtaining data under conditions existing in the field is to actually go to the field for samples (performing soil coring, water sampling, etc). This has much value (especially for predicting hazards that might result from existing waste deposits) but the studies are limited to only those wastes which have already been dumped and even then to just certain combinations of waste and soil types, waste-to-soil ratios, etc. In the field it is not possible to readily change variables to determine their effect and this lack of flexibility limits the examination to only a few factors. Many variables are completely out of the control of the experimentor. Thus the applicability of these types of studies may be limited to a relatively narrow range of environmental conditions.

Laboratory studies have the potential advantage of allowing more control over a wider range of experimental conditions. But they also have the potential disadvantage that significant field variables may be excluded because of the difficulty in simulating complex field conditions or because of improper experiment design. A compromise must be made between experiments that are an exact simulation of the field situation and those that allow varying those factors controlling the responses of interest. But if all of the controlling factors are not varied to establish their effects and if they are not included at proper levels, the empirical equations derived from this data may not be reliable in making predictions for situations where these variables are involved. It may be necessary to run preliminary experiments to see which variables have significant enough effects to merit including them in the final experimental plan.

There are two principal laboratory approaches for measuring the leachability of wastes and the migration of hazardous substances through soil. These are batchwise extractions and the continuously-leached column method, both of which are discussed below.

CONTINUOUSLY-LEACHED COLUMNS VERSUS BATCH EXTRACTIONS

The migration of chemical substances through soil is usually studied in the laboratory using columns packed with soil to a predetermined bulk density (usually approximating the field density of the undisturbed soil). These soil columns are challenged with a solution extracted from a waste by water or by some other solvent such as municipal landfill leachate, or the soil is treated with simple solutions containing the ion under study. A useful configuration is shown in Figure 5 along with illustrative plots of the data obtained.

Continuously-leached column experiments provide information as to the ability of a soil to remove chemical substances from a waste extract. However, an important limitation of this method is the time and effort required to obtain and analyze a sufficient number of samples to make predictions of migration rates and toxic hazards. This usually requires months and may even take years, depending upon the flow rate of the leaching solution through the columns. The information obtained from relatively short-term column studies cannot be relied upon to describe what will occur during years of leaching.

When setting up experiments of this type, an investigator is faced with the problem of selecting values for each experimental parameter such as leaching solvent flow-rate, head pressure, soil bulk density, column diameter meter, waste-to-soil ratio, etc. The choice of these values may not all be entirely arbitrary, but a given set will yield results which probably apply only to that particular combination of conditions and the experiment may not be very useful for making general predictions. In addition, column experiments are cumbersome and do not readily lend themselves to changes in the levels of the experimental parameters. Thus, they are slow and relatively limited in applicability.

If an experimental approach were available which is more rapid and more versatile than the usual column leaching methods, a wider range of environmental conditions could be investigated, thereby more completely describing the behavior of a waste deposited on a soil. This would also make it more practical to use factorial experiment designs. Factorial experiments allow making predictions without sacrificing reliability even in the presence of interaction between multiple variables. (Interaction exists when the effect of one factor is dependent upon the level another factor. This introduces error into the results of classical, vary-one-factor-at-a-time experimentation). A fast method would also allow making timely determinations, on demand, for each specific situation.

In previous studies of the leachability of certain metals from a number of industrial wastes and the migration of these metals through soils, this laboratory used continuously-leached columns. A batch method was employed to

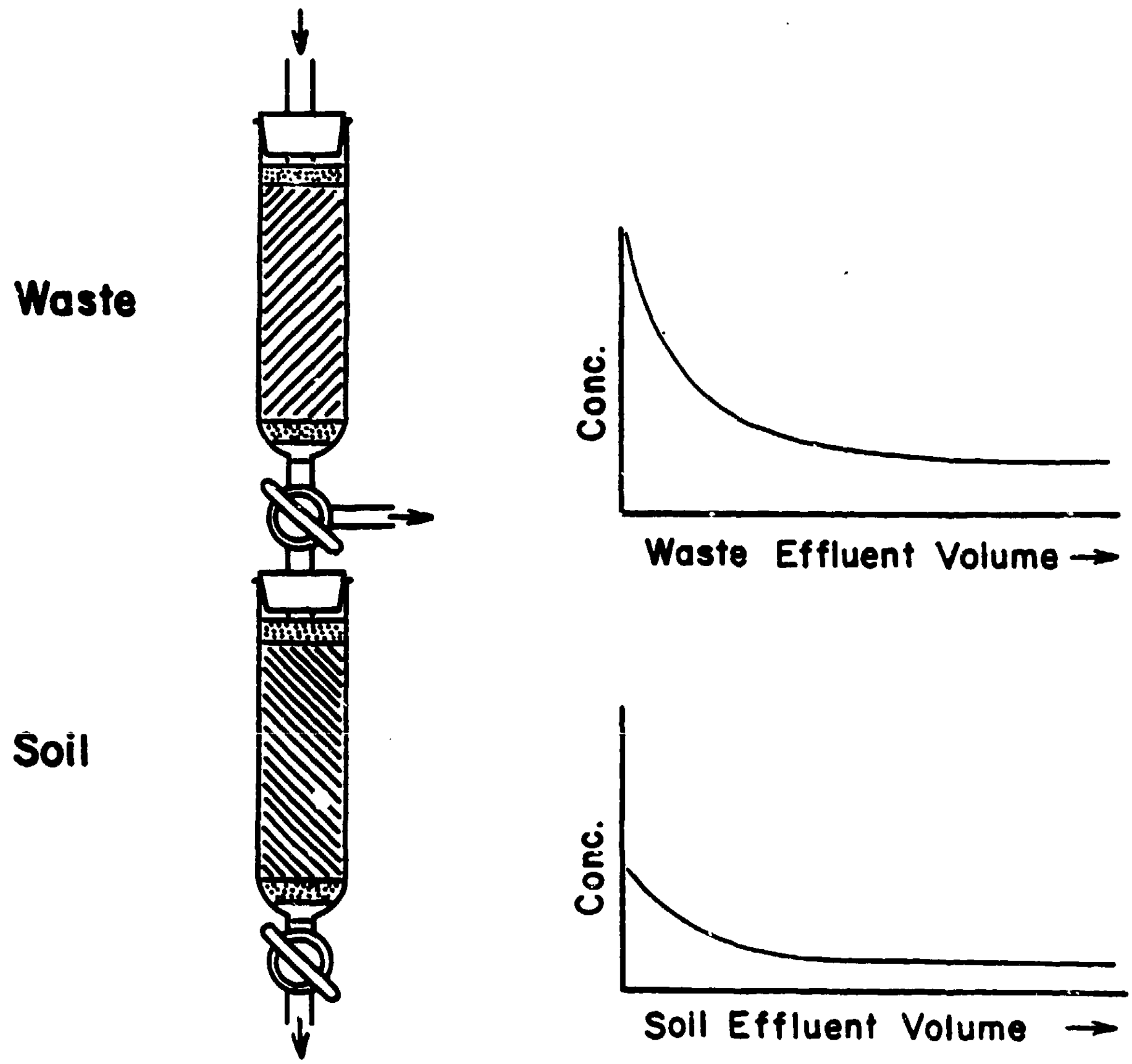

FIGURE 5. CONTINUOUSLY LEACHED COLUMNS AND ASSOCIATED OUTPUT PLOTS.

rapidly screen soils for their ability to remove these metals from the waste leachate (12). This information was then used to select soils for more detailed column studies. While examining the data, it became apparent that properly designed batch studies of the leaching of both waste and soil could provide much of the same information obtained from column studies. However, no adequate information was available as to the correlation between batch extractions and continuously-leached columns of industrial wastes and soils. As a result, samples of the industrial wastes used in the continuously-leached column studies were leached using a serial batch extraction procedure. It was found that the weights of toxic metals extracted from the wastes batchwise compared well to the column leaching (3) even though substantially greater amounts of water were present (200 to 4,800 percent versus less than 50 percent). Besides this, the results were obtained by the serial batch extraction method in only a small fraction of the time required by the column method. The serial batch method was experimentally much simpler, and it was concluded that this approach would permit the rapid investigation of the effect of a wide variety of environmental factors such as freeze/thaw and drying/resaturating cycles and similar variables that would be difficult to include in column studies.

Other investigators have used batch soil methods to study the removal of certain chemicals from waste extracts or municipal landfill leachate (13-16) and obtained results that compared well with column experiments. However, their experiments either did not allow for the changes in the waste extract composition as the waste depleted, for the further change as the extract contacted each increment of soil, and/or for the continually changing conditioning of each increment of soil, a change which depends both upon the leaching time and the soil depth. (Appendix E discusses this further.)

CORRELATING CONTINUOUS AND BATCHWISE LEACHING (2)

The data obtained from continuously-leached columns may be presented in several ways. One technique is to plot the concentration of the chemical of interest found in the waste or soil column samples, versus the cumulative volume through the column. The common way of expressing the cumulative volume is to use the cumulative pore volume calculated for the type and weight of soil employed. However, changing the kind or amount of soil will change the scale of the cumulative volume axis when pore volume is employed. Figure 6 is an example showing the difference obtained with different pore volumes (in this case 40 and 60 milliliters). The corresponding total volume in milliliters is appended for comparison.

It often is not practical or possible to determine a pore volume for a waste because of its physical form (heterogeneous suspension, liquid, etc). This problem was circumvented by using the soil column pore volume as the measure of liquid volume through the waste. It allowed correlating the waste-column output with the soil-column results in a given set of experiments. However, instead of using the soil pore volume as the principal plotting parameter, it is much more flexible to plot the observed concentration of a chemical in an extract versus the cumulative milliliters of leaching solvent per gram of waste or soil, as shown in Figure 7. This

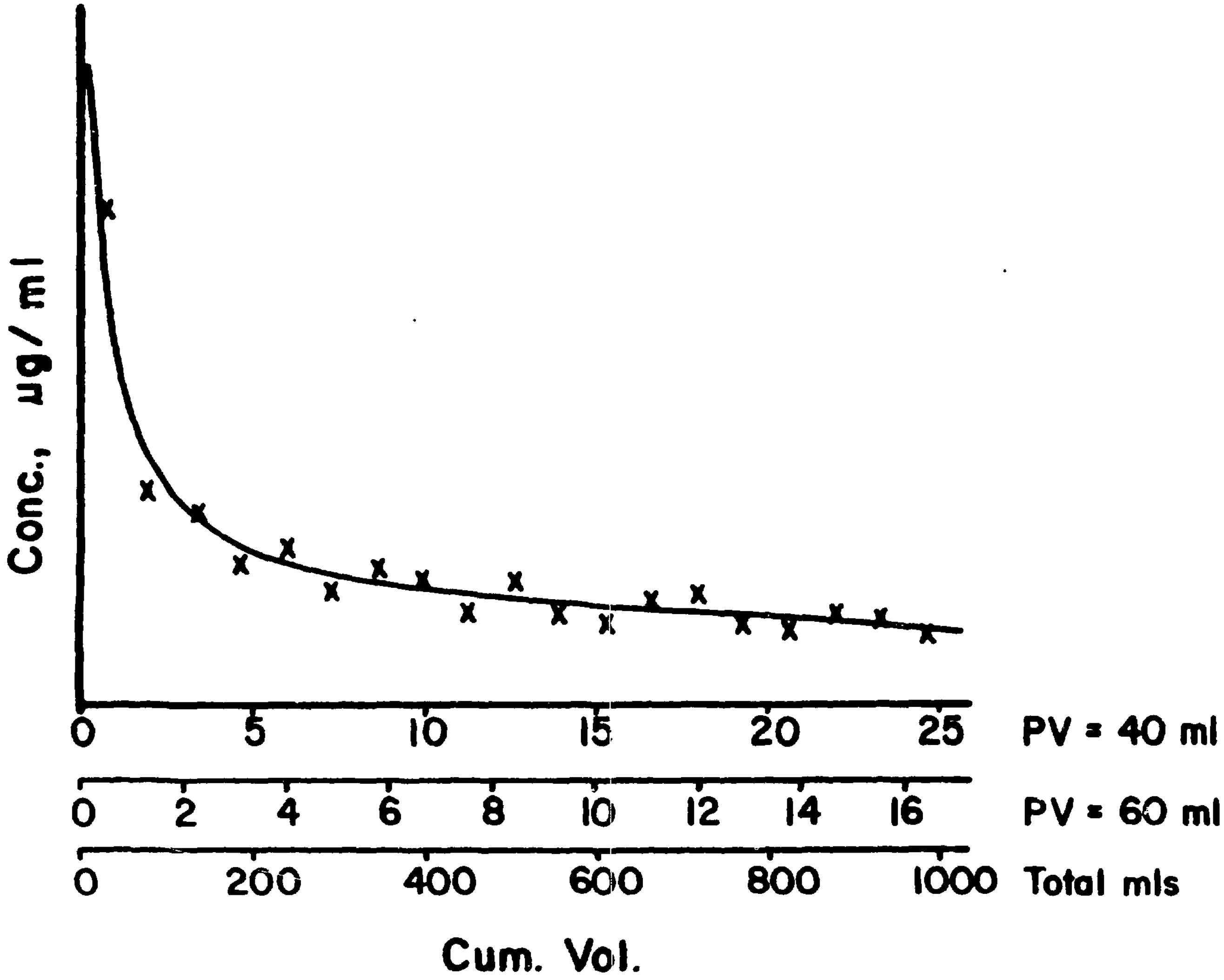

FIGURE 6. DIFFERENCES IN SCALES USED TO PLOT CUMULATIVE VOLUME.

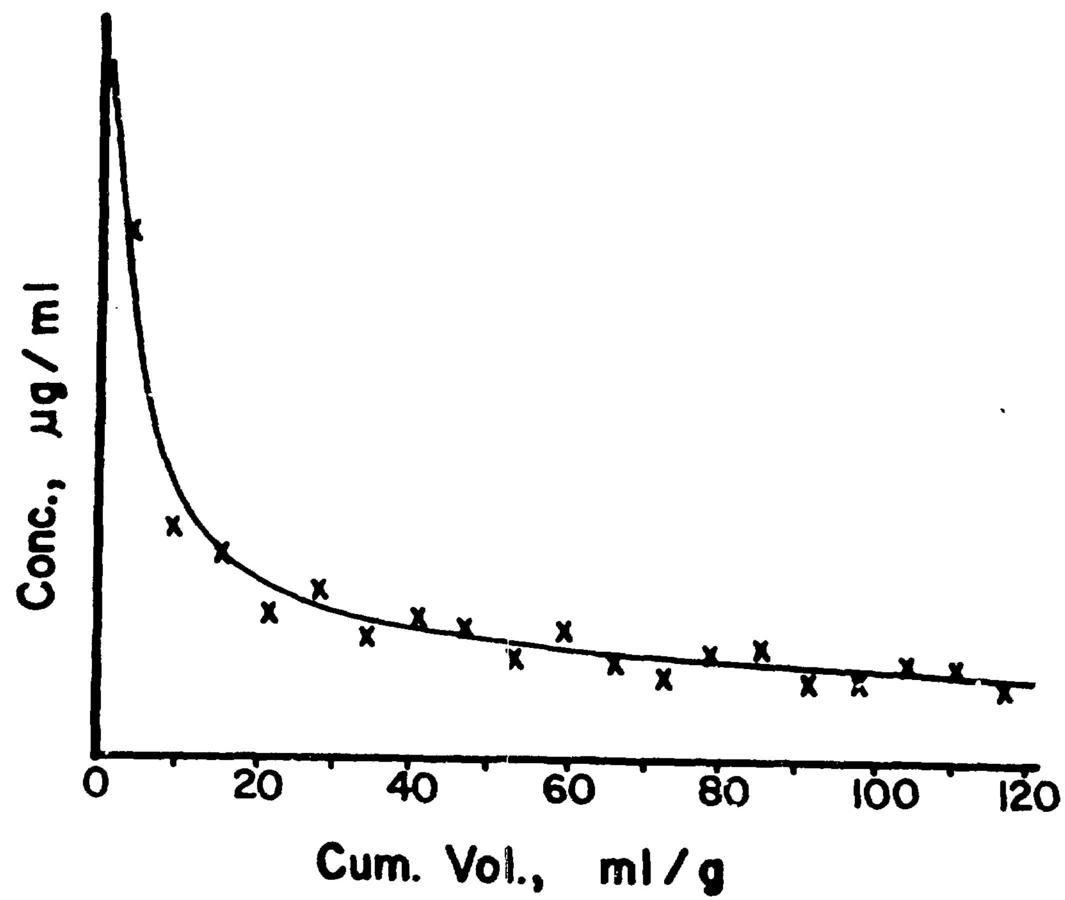

FIGURE 7. NORMALIZATION OF CUMULATIVE VOLUME USING MILLITERS PER GRAM.

makes the scaling independent of soil type, soil sample weight, and waste-to-soil ratio and allows the direct comparison of many different designs of experiments. It normalizes the results so they can be more readily correlated to a range of field conditions. The areas under the curves represent the total weight of a chemical extracted per gram of waste or soil. The weights thus obtained can be used to calculate attenuation or penetration factors for the soil.

These considerations make it possible to correlate batch and continuously-leached column experiments. Batchwise extractions can be related to continuously-leached columns by recognizing that continuous leaching is equivalent to running a series of discrete extractions spaced by the frequency of collecting the effluent sample. Figure 8 shows that the concentration of a substance in the periodic column samples can be plotted to represent the average for that sampling period. Thus, samples from the continuous leaching of a column correspond to sequential batchwise extractions by volumes of extractant equal to the volume passing through a column between the taking of samples.

When extracting a batch of waste or soil, instead of using the same volume of solvent for each successive extraction, the solvent-to-waste or -soil ratios can be graded in size, as indicated by the extraction volumes pictured in Figure 9. A small solvent-to-solids ratio should probably always be employed for the first extractions. This is usually when the concentration is changing most rapidly, so smaller increments define the curve more accurately. It also is when the soluble species will be the most highly concentrated in the extract (see Figure 1) and the ionic strength will be at its maximum. Greater dilutions would reduce this, possibly affecting the solubility of other components. After the more soluble components have been extracted, the solvent-to-solid ratio can be greatly increased, thus reducing the total number of extractions required. Obviously, the further along the cumulative milliliter per gram axis the extraction volumes extend, the longer the period of column leaching the batchwork is equivalent to.

THE BASIS FOR ACCELERATED TESTING [2]

Batch extractions are rapid compared to letting the liquid percolate through a column. If the volume of liquid used in a batch extraction can be related to the same volume of liquid passing through a waste or soil over a period of time, sequential batch extractions can be the basis for an accelerated testing of wastes and soils. First, it is necessary to consider the fraction of void space in a soil (the pore fraction) packed at a certain bulk density. The pore fraction can be calculated from the formula

$$PF = 1 - \frac{\rho_b}{\rho_p}, \qquad (1)$$

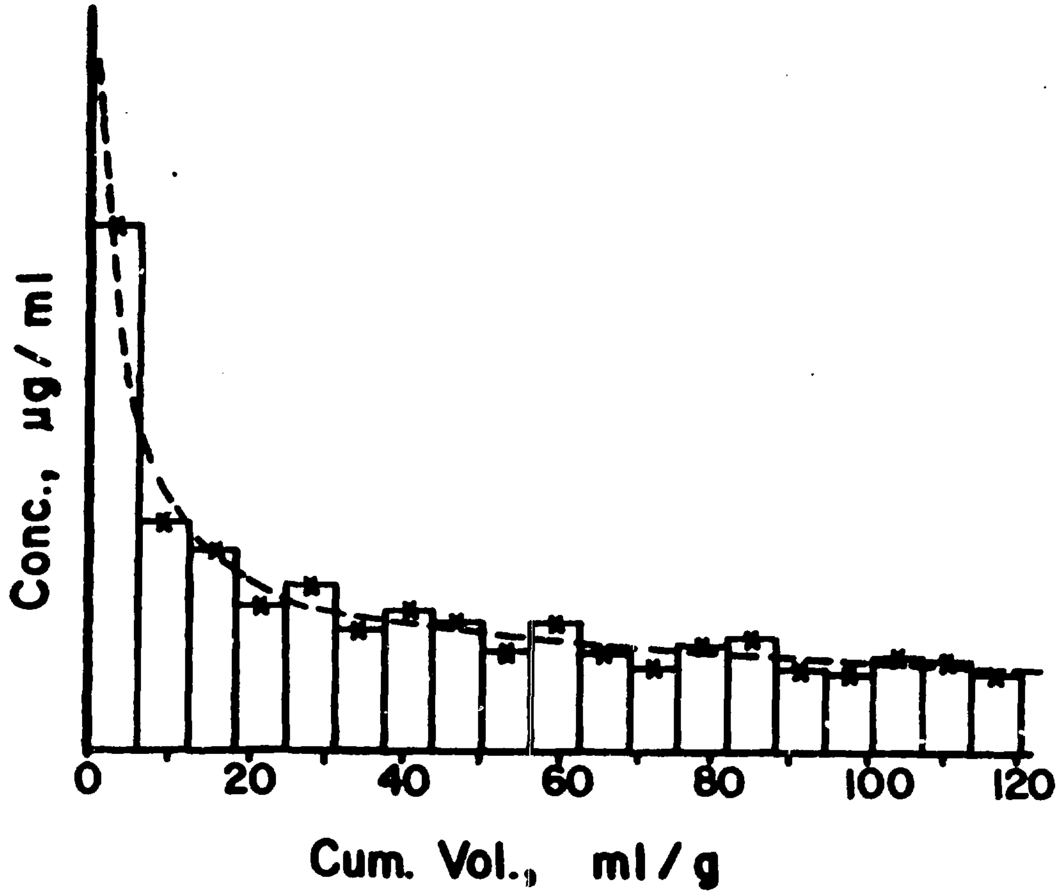

FIGURE 8. CORRELATION OF BATCH WITH CONTINUOUSLY LEACHED COLUMNS.

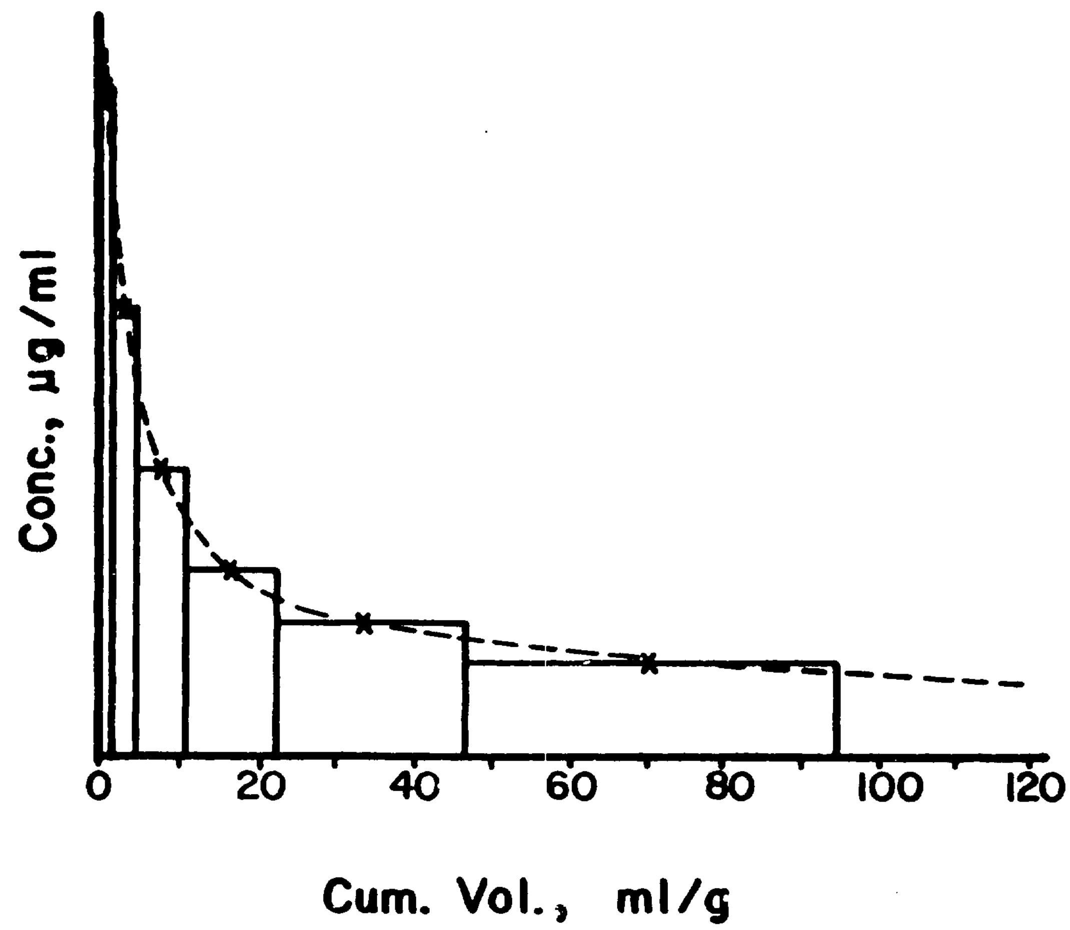

FIGURE 9. GRADED SERIAL BATCH EXTRACTIONS.

where:

PF = pore fraction,

ρ_b = bulk density, g/cm^3, and

ρ_p = particle density, g/cm^3.

Because liquid does not pass through all parts of a pore with equal efficiency, it is necessary to define an effective pore fraction, PF', for each soil, which is some fraction of F of the pore fraction calculated by Equation 1:

$$PF' = F\,(PF) = F\left(1 - \frac{\rho_b}{\rho_p}\right). \tag{2}$$

The pore volume is the total volume of void space in a given quantity of soil. This is obtained by multiplying the volume of the soil by the pore fraction

$$PV = (PF)\,(V), \tag{3}$$

where:

PV = pore volume, cm^3, and
V = volume of soil, cm^3.

An effective pore volume, PV' can be calculated by inserting the effective pore fraction in Equation 3:

$$PV' = F\,(PF)\,(V) = (PF')\,(V). \tag{4}$$

To find the effective pore volume of one gram of soil, PF_g', which is of interest because the gram is the basis for the normalization employed in this report, substitute the volume occupied by one gram of soil,

$$V = \frac{1}{\rho_b}\ \text{cm}^3, \tag{5}$$

and Equation 2 into Equation 3, which yields,

$$PV_g' = F\left(1 - \frac{\rho_b}{\rho_p}\right)\left(\frac{1}{\rho_b}\right)\ \text{cm}^3\ . \tag{6}$$

The velocity of a liquid front moving through the soil (the pore water velocity) can be related to the volume displaced by the front by first calculating the depth occupied by one gram of soil out of the total weight contained in a cubic centimeter. One gram of soil having a specified bulk density and a cross-section of one square centimeter will have a depth

$$h_g = \frac{1}{\rho_b}\ \text{cm}\ , \tag{7}$$

where:

h_g = depth, cm, of one gram of soil.

The time required for a liquid front to pass through one gram of soil (having a depth of $\frac{1}{\rho_b}$ cm) at a given velocity, i.e., the time required to fill the effective pore volume of one gram of soil with liquid, is given by

$$T = \frac{\frac{1}{\rho_b}}{v} \text{ days,} \tag{8}$$

where:

T = time, days, and
v = velocity, cm/day.

Because the number of effective pore volumes in a volume of liquid, V, is

$$\frac{V}{PV'_g} , \tag{9}$$

the time required for the passage of any volume of liquid through one gram of soil of one centimeter cross-section at a given pore water velocity can be calculated from the product of Equations 8 and 9:

$$T = \left(\frac{V}{PV'_g}\right)\left(\frac{\frac{1}{\rho_b}}{v}\right) \text{days .} \tag{10}$$

Another expression of this relationship can be obtained by substituting Equation 5 into Equation 4, which gives,

$$PV' = (PF')\left(\frac{1}{\rho_b}\right) , \tag{11}$$

and substituting this into Equation 10 yields

$$T = \frac{V\left(\frac{1}{\rho_b}\right)}{(PF')\left(\frac{1}{\rho_b}\right) v} \text{ days.} \tag{12}$$

Although the $\frac{1}{\rho_b}$'s in the numerator and denominator are numerically equal, the upper one is a height and has dimensions of centimeters, and the lower one is a volume with dimensions of cubic centimeters, so they cannot be cancelled in the general case needed to plan experiments.

Engineers and other workers in disposal practice employ the Darcian velocity (17), the rate of fall of the liquid in a reservoir above the soil, instead of the velocity of the liquid front within the soil, which was needed to develop the equations above. Because the effective pore fraction is a measure of the area available for the movement of water through soil, it also is the ratio of the Darcian to the pore water velocity. (The reduced area can be visualized as a venturi orifice which accelerates the velocity.) The Darcian velocity, v_D, therefore can be expressed as

$$v_D = PF' \, v \quad . \qquad (13)$$

The substitution of Equation 13 into Equation 12 allows the use of Darcian velocity to calculate the time that a volume of liquid takes to pass through a gram of soil:

$$T = \frac{V\left(\frac{1}{\rho_b}\right)}{v_D\left(\frac{1}{\rho_b}\right)} \text{ days.} \qquad (14)$$

The Darcian velocity may be relatively easy to determine for a lagoon having known rates of influx and evaporative loss, but the effective pore volumes of the underlying soils must be known in order to calculate how much soil was contacted by a volume of solution leaving the reservoir. The rate of fall of the reservoir thus can only be correlated with the residence time in a gram of soil of one centimeter cross-section by way of the effective pore fraction, as was done to obtain Equation 14 from Equation 10. (Using Darcian velocity directly instead of converting to pore water velocity yields a number having different dimensionality and it can lead to planning experiments which employ incorrect batch sizes to represent a given contact time.)

To illustrate the use of these generalized equations, assume that a soil has a bulk density of 1.60 g/cm^3, a particle density of 2.65 g/cm^3, and that effectively 90 percent of the pore space transports liquid (18). (These values are representative of the clays used in the experimental work presented in this report.) Thus, from Equation 2, the effective pore fraction is

$$PF' = 0.90 \left(1 - \frac{1.60}{2.65}\right) = 0.357$$

and the effective pore volume per cubic centimeter is

$$PV' = (0.357)\,(1.0) = 0.357 \text{ cm}^3 .$$

The volume occupied by one gram of soil is

$$V = \frac{1}{1.60} = 0.625 \text{ cm}^3 ,$$

so the effective pore volume for the one gram of soil is

$$PV'_g = 0.90 \left(1 - \frac{1.60}{2.65}\right)\left(\frac{1}{1.60}\right) = (0.357)(0.625) = 0.223 \text{ cm}^3.$$

If a liquid penetrates this soil at a pore water velocity of 1×10^{-5} cm/sec (which, with 86,400 sec/da, is 0.864 cm/da), one milliliter of liquid will penetrate one gram of soil in

$$T = \left(\frac{1}{0.223}\right)\left(\frac{0.625}{0.864}\right) = 3.24 \text{ days.}$$

Thus, an extraction with 2 milliliters per gram of soil is equivalent to $2 \times 3.24 = 6.48$ days of penetration in the field or in a column. Table 12 lists the liquid-to-solid ratios employed in this study together with the cumulative volumes and equivalent exposure times for liquid front velocities of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} centimeters per second through a typical clay. This correlation is displayed graphically in Figure 10.

The pore water velocity of the liquid in a soil underlying a specific waste-disposal site must be calculated or determined experimentally to be able to choose the correct correlation from the table. However, the flow rate determining the factor will often be the penetrability of the layer of waste. Table 12 also applies to the leaching of waste because the volume of liquid passing through a column of waste will ordinarily be the same as through the soil beneath it, as previously discussed.

TABLE 12. CORRELATION BETWEEN EXTRACTION VOLUME AND PENETRATION TIME (2)

Extraction Number	Water Added, (ml/g)	Cumul. Vol., (ml/g)	Equivalent Days of Penetration* @10^{-4} cm/sec	@10^{-5} cm/sec	@10^{-6} cm/sec
1	2	2	0.65	6.5	65.
2	3	5	1.62	16.2	162.
3	6	11	3.56	35.6	356.
4	12	23	7.45	74.5	745. (2.0 yr)
5	24	47	15.2	152.	1520. (4.2 yr)
6	48	95	30.8	308.	3080. (8.4 yr)
7	96	191	61.9	619.(1.7 yr)	6190. (16.9 yr)

*At the specified pore water velocity through a soil having an effective pore volume of 0.223 ml/g.

Tables similar to Table 12 can be calculated for soils having other pore volumes using Equation 10 or 12. If Darcian velocities are desired in the table, then Equation 14 can be employed. (A table using Darcian velocities is shown in Appendix A.)

The waste composition changes as components are leached from the waste. Each succeeding portion of extract will therefore generally have a different composition as shown in Figure 11. Besides being challenged by a changing solution, the soil's ion-removal characteristics continually change with time as the soil becomes conditioned and loaded by the passage of waste extracts. Since each portion of waste is changed by passage through soil,

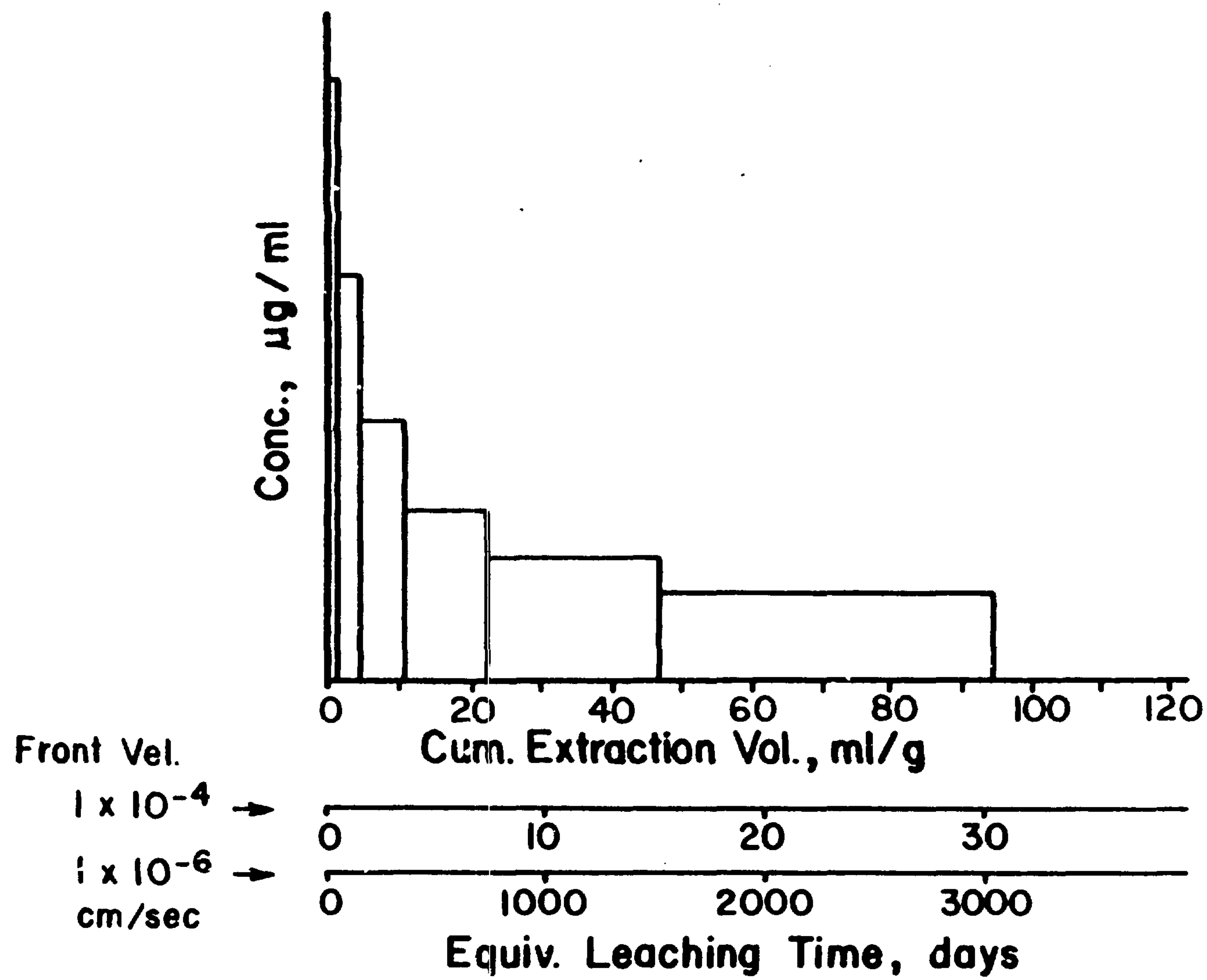

FIGURE 10. RELATING BATCH VOLUMES TO LEACHING TIMES FOR SOILS HAVING A PORE VOLUME OF 0.223 ml/g.

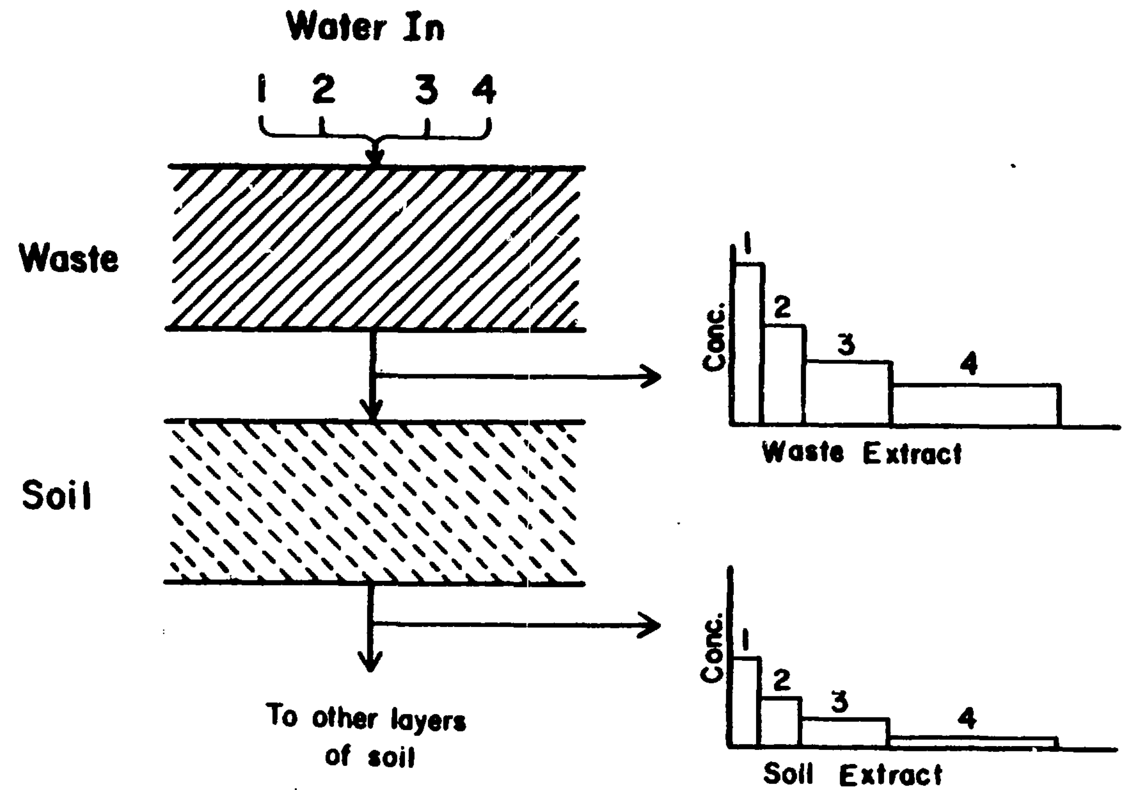

FIGURE 11. THE RESULTS OF CHALLENGING SOIL WITH SUCCESSIVE EXTRACTS OF WASTE.

the conditioning each succeeding segment of soil receives is different and each segment therefore may remove different portions of the various ions present in the waste extract. So although the soil segments start out the same, in effect they become different soils due to the passage of the different waste extracts.

The soil removes ions from the waste, but the waste extract can also displace ions from the soil. In addition, soil can pick up a specific ion from a waste solution of one composition and then give it up again as the liquid composition changes. The soil may also give up ions later because of intervening conditioning of the soil by the passage of the changing waste extract solution. If extract samples were taken within a layer of soil, it would be possible to study this dynamically-changing situation. This can be accomplished by placing sampling ports in the side of a soil column, as shown in Figure 12. The same results can be attained in a shorter time with far fewer equipment difficulties by putting waste extracts on successive batches of soil and taking a sample after each extraction. A batch of soil then will represent a segment of soil from a soil layer.

Normally, the distribution of substances retained by the soil column is determined after leaching is concluded by sectioning and analyzing the soil column. But this serial batch approach, with sampling between batches of soil (described in Section 4, page 10) allows perceiving what is happening within a bed of soil and provides data which could permit extrapolating to the effect of thicker strata — something which cannot be done with validity from experiments with only a single layer or from experiments which use simpler conditions. It is re-emphasized that batchwise testing also yields its information in a small fraction of the time required by columns or field studies.

UTILIZATION OF BATCH EXTRACTION DATA

A variety of calculations can be performed using the results from the graded serial batch extraction experiments on wastes and soils. Table 13 lists those which were done for this report, giving the derivation of the tables presented in Section 6. In Table 13, W refers to the waste extract, and I, II, and III, identify the extract from the first, second, and third batches of soil, respectively. The subscripts affixed to these symbols identify the number of the extraction in the series of seven employed. The resulting character refers to the amount of a chemical species found in the extract, expressed in terms of micrograms per gram of waste or soil. Each calculation utilizing these quantities is explained in the following paragraphs.

Calculating the Weight of a Substance Leached from Waste

The weight of a substance leached per gram of waste can be calculated by multiplying the concentration of the substance observed in the extract by the volume of water or other extraction liquid used, divided by the weight of waste being extracted. In consistent units: microgram/milliliter x milliliter/gram = microgram/gram waste. Thus, the weight extracted by each extraction in the series listed in Table 1 was obtained by multiplying the

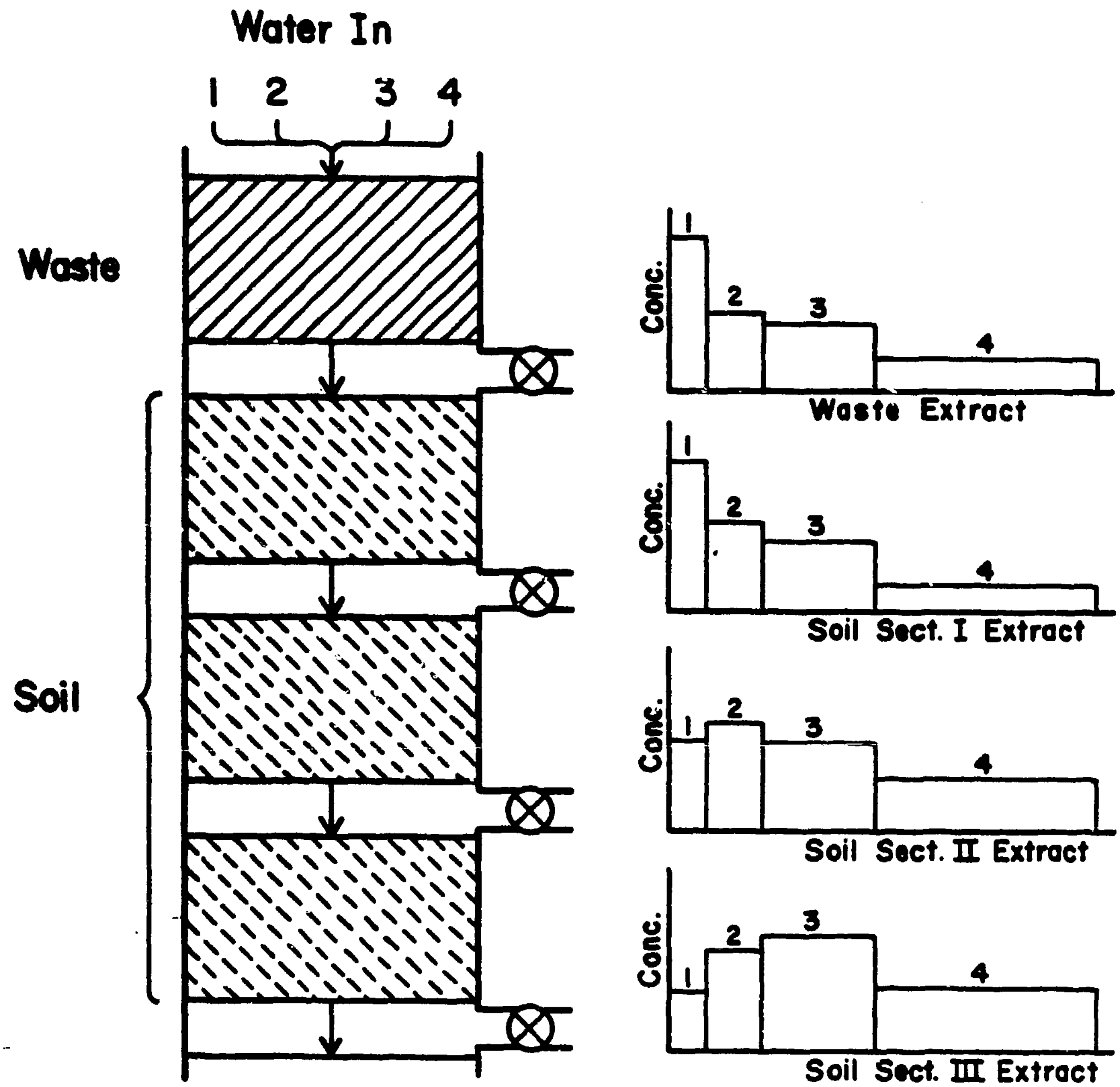

FIGURE 12. CHALLENGING MULTIPLE SOIL SEGMENTS WITH SUCCESSIVE EXTRACTS OF WASTE.

TABLE 13. CALCULATIONS MADE FROM THE SERIAL BATCH EXTRACTION DATA

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Extraction Number	Layer	Amount Penetrating: Averaged Raw Data ug/ml	Amount Penetrating: ug/g	Amount Retained this Extract ug/g	Cumulative Total Challenge ug/g	Cumulative Total Retained ug/g	Fraction Retained: From this Extr.	Fraction Retained: From Cumulative Total Challenge	Pene-tration Factor	Distribution Coefficients: Including Soil: Distrib. Ratio	Distribution Coefficients: Including Soil: Slope, Degrees	Distribution Coefficients: From Solution Only: Distrib. Ratio	Distribution Coefficients: From Solution Only: Slope, Degrees
			Out (In)	In-Out	Σ In	Σ(In-Out)	$\frac{\text{In-Out}}{\text{In}}$	$\frac{\Sigma(\text{In-Out})}{\Sigma\text{In}}$	$\frac{\text{Out}}{\text{In}}$	$\frac{\Sigma(\text{In-Out})+\text{Soil}}{\text{Out}}$		$\frac{\Sigma(\text{In-Out})}{\text{Out}}$	
1	W	-	W_1	---	---	---	---	---	---	---	---	---	---
	I	-	I_1	W_1-I_1	W_1	W_1-I_1	$\frac{W_1-I_1}{W_1}$	$\frac{W_1-I_1}{W_1}$	$\frac{I_1}{W_1}$	Eqn.19	Tan^{-1}Eqn. 19	Eqn.19 with $I_o=0$	Tan^{-1} ÷
	II	-	II_1	I_1-II_1	I_1	I_1-II_1	$\frac{I_1-II_1}{I_1}$	$\frac{I_1-II_1}{I_1}$	$\frac{II_1}{I_1}$	Eqn.21	Tan^{-1}Eqn. 21	Eqn.21 with $I_o=0$	Tan^{-1} ÷
	III	-	III_1	II_1-III_1	II_1	II_1-III_1	$\frac{II_1-III_1}{II_1}$	$\frac{II_1-III_1}{II_1}$	$\frac{III_1}{II_1}$	Eqn.=21	Tan^{-1}Eqn. =21	Eqn.=21 with $III_o=0$	Tan^{-1} ÷
	I+II		$\frac{II_1}{2}$	$\frac{W_1-II_1}{2}$	$\frac{W_1}{2}$	$\frac{W_1-II_1}{2}$	$\frac{W_1-II_1}{W_1}$	$\frac{W_1-II_1}{W_1}$	$\frac{II_1}{W_1}$	Eqn.22	Tan^{-1}Eqn. 22	Eqn.22 with I_o, $II_o=0$	Tan^{-1} ÷
	I+II+III		$\frac{III_1}{3}$	$\frac{W_1-III_1}{3}$	$\frac{W_1}{3}$	$\frac{W_1-III_1}{3}$	$\frac{W_1-III_1}{W_1}$	$\frac{W_1-III_1}{W_1}$	$\frac{III_1}{W_1}$	Eqn.23	Tan^{-1}Eqn. 23	Eqn.23 with I_o, II_o, $III_o=0$	Tan^{-1} ÷
2	W	-	W_2	---	---	---	---	---	---	---	---	---	---
	I	-	I_2	W_2-I_2	W_1+W_2	$(W_1-I_1)+(W_2-I_2)$	$\frac{W_2-I_2}{W_2}$	$\frac{(W_1-I_1)+(W_2-I_2)}{W_1+W_2}$	$\frac{I_2}{W_2}$	APPLY ABOVE EQUATIONS			
	II	-	II_2	I_2-II_2	I_1+I_2	$(I_1-II_1)+(I_2-II_2)$	$\frac{I_2-II_2}{I_2}$	$\frac{(I_1-II_1)+(I_2-II_2)}{I_1+I_2}$	$\frac{II_2}{I_2}$				
	III	-	III_2	II_2-III_2	II_2+II_2	$(II_1-III_1)+(II_2-III_2)$	$\frac{II_2-III_2}{II_2}$	$\frac{(II_1-III_1)+(II_2-III_2)}{II_1+II_2}$	$\frac{III_2}{II_2}$				
	I+II		$\frac{II_2}{2}$	$\frac{W_2-II_2}{2}$	$\frac{W_1+W_2}{2}$	$\frac{(W_1-II_1)+(W_2-II_2)}{2}$	$\frac{W_2-II_2}{W_2}$	$\frac{(W_1-II_1)+(W_2-II_2)}{W_1+W_2}$	$\frac{II_2}{W_2}$				
	I+II+III		$\frac{III_2}{3}$	$\frac{W_2-III_2}{3}$	$\frac{W_1+W_2}{3}$	$\frac{(W_1-III_1)+(W_2-III_2)}{3}$	$\frac{W_2-III_2}{W_2}$	$\frac{(W_1-III_1)+(W_2-III_2)}{W_1+W_2}$	$\frac{III_2}{W_2}$				

observed concentration in micrograms/milliliter by the extraction volumes listed in the second column of the table.

Since one percent concentrated nitric acid was added to keep ions in solution, and ten percent by volume of lithium nitrate solution was added to suppress interference from alkaline metals and earths in the analysis by argon plasma emission spectrophotometer, the observed concentration must be adjusted to obtain the actual concentration. (The correction for the lithium addition was accomplished by programing the concentrations printed out by the spectrophotometer.) The corrected raw data from replicate extractions is averaged and posted as column C, Table 13. Multiplying each waste-sample concentration by the appropriate above-mentioned factor yields the corresponding result in column D.

Calculating the Weight of a Substance Penetrating the Retained on Soil

The weight of a substance extracted per gram of soil is calculated for each extraction in the same manner as described above for waste. The multiplying factors remain the same because the extraction volumes in Table 1 were adjusted for all the soil batches to maintain the same milliliter/gram as for the waste.

The amount penetrating a batch of waste or soil becomes the challenge to the next batch. Thus, the μg/g out of the W_1 becomes the μg/g in for I_1. The weight of a substance coming in to a batch of soil minus the weight out equals the weight retained by the soil during the extraction. In this way, the values entered in column D, Table 13 are used to produce column E. The fraction retained by a soil from an extract is calculated by dividing the results in column E by the weight coming in, as indicated in column H.

When ever a minus sign appears in the table, it means that the soil either gave up some of that substance which it had previously picked up from the waste leachate, or it gave up some originally present in the soil before being exposed to that waste. If the original analyzed concentrations were near the detection limit, then, because of the normal deterioration of the precision of an assay near its detection limit, less significance can be assigned to the corresponding derived values and to the appearance of a minus sign.

A useful property of the fraction retained from the cumulative total challenge is that when the soil is yielding the elment of interest and it is desired to know how many times greater the amount existing is greater than the challenge,change the minus sign on the value in column I to a plus and add 1.00. Thus, a fraction of -8.05 retained from the total challenge means that 9.05 times as much of that element was given up as was present in the total challenge.

The results of passing one waste extract through the three soil batches can be presented as in the histogram of Figure 13. The height of the histogram bar labeled W represents the mass in micrograms of a substance extracted per gram of waste. This is the challenge to the first batch of soil, which represents the top layer in a bed of soil. The height of the bar labeled I shows the concentration of the species

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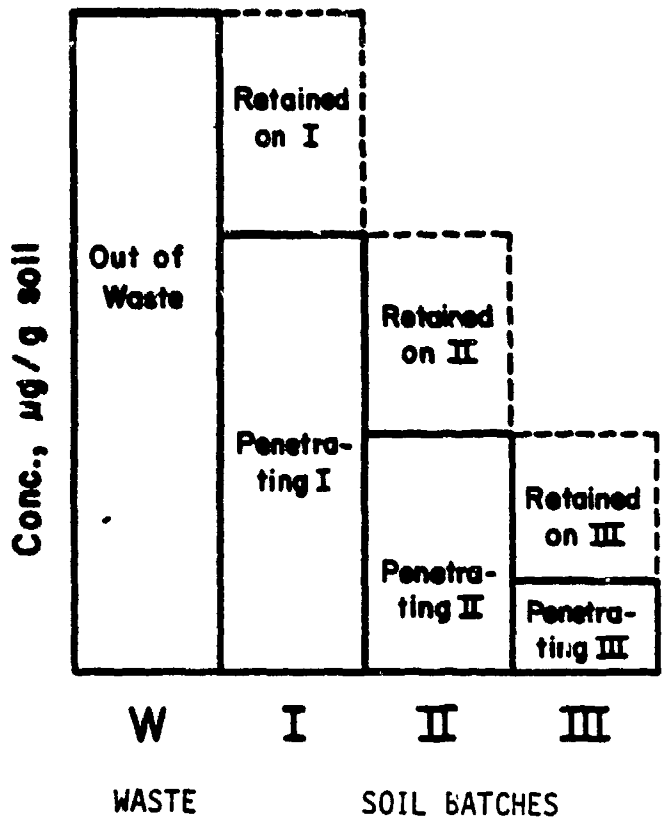


FIGURE 13. HISTOGRAM SHOWING THE PENETRATION AND RETENTION OF A SPECIES BY SOIL FOR ONE SET OF EXTRACTIONS.

penetrating the batch representing the next layer of soil, and the difference in height between I and W is the amount of the species retained per gram of soil.

The cumulative sum of the challenges to a given batch (layer) of soil is obtained by summing up the results for the successive extractions that have challenged that batch. Thus, as seen in column F of Table 13, the cumulative sum of the challenge to soil II_2 is $I_1 + I_2$. The cumulative total retained can be calculated in a similar manner, as indicated in column G, and used to determine the fraction retained from the total challenges, as recorded in column I. These values are of particular interest in studies of soil capacity.

Calculating Penetration Factors

The quantity of a substance penetrating a batch of soil divided by the amount of challenge (both found in column D) can be defined as the Penetration Factor (the reciprocal of the Attenuation Factor), which is found in column J of Table 13. This is the fraction penetrating the soil and it can also be viewed as the decimal percent. Multiplying a challenge by the Penetration Factor gives the amount penetrating. If the Penetration Factor is greater than 1.0, it indicates that the soil is either yielding material previously held up during the passage of extracts, or that some is being displaced out of that originally present in the soil.

The penetration factor calculated in column J is for the corresponding extraction only and is not cumulative. The cumulative penetration factor can be obtained by subtracting the cumulative fraction retained, column I, from 1.00.

Calculating Distribution Coefficients [19]

The chromatographic distribution coefficient, K, is defined as the concentration of a species in the solid phase divided by the concentration in the liquid phase. (20) This distribution ratio (columns K and M of Table 13) is the slope of the line showing the relationship between the concentration adsorbed on the soil and the concentration remaining in the solution. The angle of the slope at that point is the arctangent of K. (The angles are tabulated in columns L and N.) At low concentrations, the relationship is usually linear in simple systems, but K typically decreases with increasing amounts of solute, i.e., as the sites are occupied by increased amounts of the substance being studied. Large K's show a high relative retention. Experiments to determine K are normally done at constant temperature because K is temperature-dependent (changing the temperature changes the position of a point on the plot showing the amount of a species removed from the solution by the soil) and so the curves are called isotherms.

Temperature is not the only parameter which affects the distribution between phases. The pH, the ionic strength, the presence of competing ions, the previous history of the solid, its current surface energy and effective surface area, in short, the total conditions must be uniform because each of

these things can affect the distribution ratio. So, iso-conditions are needed, not just iso-therm, while experiments are run if this kind of plot is to be obtained. If the conditions are changed to some other level, a distinctly different set of points can be obtained. (If conditions are allowed to vary at random, then randomly located points can be expected; if conditions are varied according to some plan, like a factorial experiment design, then their effect on the distribution coefficient can be examined. For the results to apply to a field situation, field conditions must be simulated in the experimental array.)

These lines are called <u>adsorption</u> isotherms, but more than adsorption can be involved in removing ions from solution. Besides dispersion and dipole forces, hydrogen bonds and weak covalent bonds—including acid-base interactions and complex formation—strong covalent bonding responsible for chemisorption, precipitation, and even mechanical filtration, all could contribute to the removal of a substance from solution. So what is called adsorption isotherms really are plots of removal or retention in iso-conditions, that is, they are plots of temporary retention under a given set of conditions. Even irreversibility is condition-dependent. An insoluble compound may become soluble as the conditions change, e.g., as the extraction progresses or as the soil changes.

The distribution coefficient, K, is not for adsorption alone, but for all equilibria causing retention or displacement. K can be computed on several different bases: as an experiment is started, the concentration of a substance being studied will probably be zero in the solid phase if a chromatographic substrate is being worked with, but in soil work, any compounds present in the soil which contain the ion(s) being studied are a potential source that can contribute to its concentration in the leachate solution passing through the soil. The waste leachate is a potentially powerful solubilizer and displacer of components in the soil, i.e., the soil can act as a reservoir of Pb, Cd, Ti, Zn, etc, which the waste leachate can cause to bleed off and carry on down to ground-water. A negative slope to the retention isotherm shows the soil is giving up the ion, acting as a source. The waste is the cause of this kind of pollution, but not the source—the soil is the source.

The distribution coefficient, K, can be based on a unit volume of solid adsorbant, or a unit weight, which is employed in this report. The concentration expressed in microgram/gram soil can refer to the number of micrograms of ion removed from a given solution challenging the soil, it can represent all that the soil has removed from a series of solutions (as in column M of Table 13), it can be a total which also includes all that was originally present in the soil (Table 5) and therefore potentially available to the equilibria (as used in column K), or the total concentration in the soil can include just that portion known to be soluble in or displaced by the solution challenging it.

The concentration in the solution is usually expressed as weight per unit volume, such as micrograms per milliliter, and the resulting units for K are milliliters per gram, as shown in equation 15:

$$K = \frac{\mu g/g}{\mu g/ml} = \mu g/g \times ml/\mu g = ml/g. \tag{15}$$

But, even though it is the liquid that is being analyzed, it is the soil that is being studied. The concentration is measured as micrograms per milliliter, but of more direct importance is the weight of soil contacted by this solution. If the concentration observed in the liquid, micrograms/milliliter, is multiplied times the total amount of liquid put on the soil, expressed as milliliters/gram, Equation 16 shows that the concentration in the solution is obtained in terms of micrograms per gram of soil contacted:

$$\mu g/ml \times ml/g = \mu g/g \tag{16}$$

Then, as seen in Equation 17 the ratio, K, becomes a properly dimensionless constant as a result of employing this more fundamental relationship:

$$K = \frac{\mu g/g}{(\mu g/ml)\ (ml/g)} = \frac{\mu g/g}{\mu g/g} \tag{17}$$

As previously discussed, the conditions for retention can be expected to differ with soil depth because each layer of soil is challenged by a different solution matrix. The conditions also will change with time as the leaching of the waste progresses and generates a solution of changing composition. So that this latter effect could be examined, equations were derived to calculate the distribution coefficient for every succeeding extraction of the waste. The distribution of a species between the solid and the liquid phases will be the sum of the amount originally on the soil and the amounts retained from each of the successive waste extracts, all divided by the amount in the solution leaving that batch of soil. Thus, the distribution ratio resulting from n extracts passing through soil batch I can be computed by the following equation:

$$K_{I_n} = \frac{I_o + (W_1 - I_1) + (W_2 - I_2) + \ldots (W_n - I_n)}{I_n} \tag{18}$$

$$= \frac{I_o + \sum_{i=1}^{n} (W_i - I_i)}{I_n} = \text{Slope of adsorption isotherm,} \tag{19}$$

where,

I_o = concentration of a species originally on the soil, µg/g,

I_i = concentration of the species in the ith extract passing through soil batch I, µg/g, and,

W_i = concentration of the species in the ith extract out of the waste, µg/g.

The concentrations of the solutions after equilibrium has been established (the output concentrations) are used in these calculations instead of the starting (the input) concentrations.

The distribution ratio will ordinarily be different for the second batch of soil because it is being challenged and conditioned by a different solution — a solution which has been modified by passing through the first batch of soil. The distribution coefficient for the second soil batch can be calculated for each extraction using the following formula:

$$K_{II_n} = \frac{II_o + (I_1 - II_1) + (I_2 - II_2) + \ldots (I_n - II_n)}{II_n} \tag{20}$$

$$= \frac{II_o + \sum_{i=1}^{n} (I_i - II_i)}{II_n} = \text{Slope.} \tag{21}$$

The distribution coefficients for each extraction passing through the third batch of soil are calculated in a similar manner using the differences in concentration between the second and third soil batches.

The experiments generally will be done with the same kind of soil in each batch, so the concentration of a species originally in the batch of soil, $I_o = II_o = III_o$. If only the amount of a species removed from the solution is to be considered in the distribution coefficients being calculated, neglecting that which is originally present in the soil, set I_0, II_0, and III_0 all equal to zero.

The effect of different soil-to-waste ratios can also be checked in this experiment by calculating distribution coefficients for the waste extract challenging the first two soil batches and then all three batches:

$$K_{(I+II)_n} = \frac{I_o + II_o + \sum_{i=1}^{n} \frac{(W_i - II_i)}{2}}{1/2\ II_n}, \tag{22}$$

for a 2:1 soil-to-waste ratio, and

$$K_{(I+II+III)_n} = \frac{I_o + II_o + III_o + \sum_{i=1}^{n} \frac{(W_i - III_i)}{3}}{1/3\ III_n} . \qquad (23)$$

for a 3:1 soil-to-waste ratio.

The effect of changes in the extract due to passage through the soil also can be obtained by calculating:

$$K_{(II+III)_n} = \frac{II_o + III_o + \sum_{i=1}^{n} \frac{(I_i - III_i)}{2}}{1/2\ III_n} , \qquad (24)$$

and comparing it with the results from $K_{(I+II)n}$ (Equation 22).

Since a distribution coefficient is the slope of the retention curve (the "isotherm") at the point represented by the numerical values of the numerator and denominator in the ratio, the angle whose tangent is K can be depicted on a graph by an appropriately oriented line segment. This seemingly would allow drawing a curve of retention under iso-conditions (an "isotherm"). But an examination of the experimental data in Section 6 reveals, as postulated when designing this experimental approach, that there is a considerable change in K for most ions as the leaching of the waste progresses and as the waste passes down through the soil. This shows that in the real field situation, or in experiments which approximate it, constant conditions for adsorption will not exist during the presentation of the challenge. This means that the remainder of the curve cannot be determined. Only a family of line segments will be obtained from the K values calculated for each waste and soil extract, with each line segment representing the distribution ratio under a different set of conditions. An example is depicted in Figure 14 using columns D, G, and N from the data giving the leaching of cadmium from zinc secondary-refining sludge on Chalmers soil (Table 63).

Although there does not seem to be much value in plotting adsorption isotherms for these complex situations, it is of interest to obtain distribution coefficients from valid observations because they are employed in chromatographic theory. For instance, the net retention volume, V_n, required to elute the peak of a given chemical species, can be calculated from

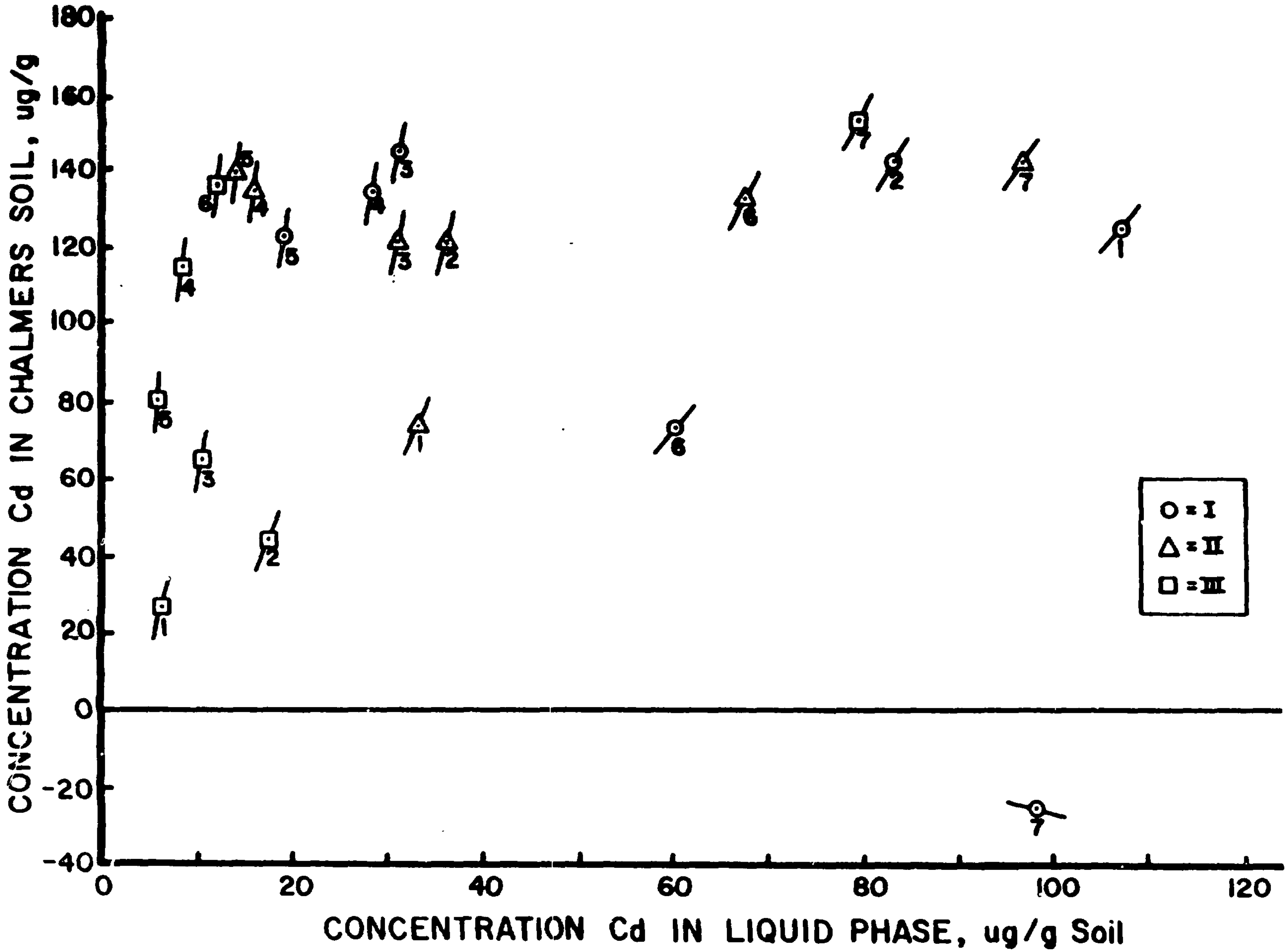


FIGURE 14. SEGMENTS OF ADSORPTION "ISOTHERMS" SHOWING THE EFFECTS OF SOIL DEPTH (LAYERS I TO III) AND EXTENT OF LEACHING (EXTRACTIONS 1 TO 7) ON CADMIUM DISTRIBUTION.

$$V_n = K\,V_s \quad , \qquad (25)$$

where V_s is the volume of the stationary phase. (21) If we can relate K for a given hazardous material to environmental-experimental factors having significant effects, then the resulting equations may be usable for predicting its movement down to ground water.

A distribution ratio of, e.g., three, would be obtained whether the concentrations in the solid and liquid phases are 3/1 or 300/100. But what ultimately determines the current hazard is the concentration existing in the liquid phase, and the distribution ratio does not directly disclose this. The concentration resulting at each soil depth and for each stage of the leaching is given by the raw data from the serial batch extraction procedure. (This information can be presented in a table as in the example in Appendix B.)

COMMENTS ON PREDICTION EQUATIONS (19)

The two main approaches to describing a physical situation in mathematical terms are either to construct a model or to derive an empirical equation. Both were examined to see which was likely to be the best for obtaining prediction equations.

Models

The kind of model of interest here is a mathematical or at least a dimensional analysis which expresses the relationship between the important variables of a physical system. Although mathematical models may be derivable to describe relatively simple individual phenomena (i.e., observations of experiments on simple systems, etc), combining these to accurately describe a more complex system will be possible only if all the significant phenomena are known and if functions, weighting factors, etc, relating them (which must be determined by observations) are included to balance their relative effects on the system's response to a variation. Therefore, ever with the best model—one which includes all of the significant details—experimental work ordinarily will have to be done to measure the effect of each factor so that a prediction equation can be derived. The result is an equation with empirically derived coefficients, but with a form constructed from theory. (Running experiments also commonly provides additional insight into the physical system, enabling revising the model.) Thus, for a model to be useful for making predictions, the terms must ordinarily be amenable to elucidation by experiments relatable to the real field situation. That is, the experiments may have to include variables such as temperature, ionic environment, residence time, etc., at the levels they occur in the field. Experiments therefore should not be arbitrarily simplified. Holding an experimental factor (e.g., concentration) constant can be the experimental equivalent of deleting a variable from a model or making an assumption in modeling. (Conversely, assumptions in the initial formulation of a model can be equivalent to running experiments under a limited range of conditions, thus excluding a range of applicability of the model.) Simplifications can be introduced (assumptions in theories, approximations in experiments), but it is always necessary to

determine whether the effects of these simplifications are significant, i.e., how far the final result comes from representing the real life circumstances.

Unfortunately, instead of attempting to list all of the significant variables and then carefully working out the relationship between them, it is a common practice to pick a model developed for some perhaps related application and apply it to the new situation without considering whether the model includes all of the variables which have statistically significant effects in the new situation, much less seeing whether the functional relationship between the variables is correctly expressed. The dangers of being too arbitrary about the choice of model can be seen from a simplified example: An investigator may be interested in predicting the leachability of cadmium from NiCd battery-production waste by landfill leachate (the liquid produced by the percolation of water through municipal refuse). If in a previous study he developed a model using water as the leaching solvent, and it is desired to apply this model to the results obtained from experiments in which landfill leachate was used, the simplifying assumption might be made that since both liquids are aqueous, the other ions present in the landfill leachate would not affect the basic nature of the leachability of the cadmium ion. In actuality, the cadmium leaching by landfill leachate is adequately described by a linear equation whereas the data from the original investigation dictated use of a power function (Figures 15 and 16). Nevertheless, the data from the landfill leachate study would be forced to fit the power function model by regression analysis. The coefficients in the resulting equation,

$$Y = 14000\ x^{-1.87}\ , \tag{26}$$

then express the deviation of the experimental data from the presumed model. In a more complex example, the differences between the response surface predicted by the Lapidus-Amundson diffusion equation and that found experimentally for the movement of cadmium through soils is expressed by the surface of Figure 17, which presents a small section of the sum of squares surface (for Dispersion Coefficient = 2 cm^2/day) expressing the difference between the experimental data and the model:

$$\text{Conc. of Ion} = \frac{\text{Pore Water Velocity}}{4\ (\text{Dispers. Coeff.})} + \frac{K_1}{\text{Pore Fraction}} - K_2 \cdot \tag{27}$$

These misfits occur when experimental data is used to derive coefficients for the wrong model. If the model should happen to describe the data reasonably well over a part of the concentration range or leaching time, and the equation yields some predictability, it probably will be thought of as the correct model even though it is a hybrid, an incorrect or incomplete model with empirically-derived coefficients. Fortunately, experimentally determined coefficients will help to compensate for deficiencies in the mathematical structure, but the range of applicability of the formulation will seldom be known and its use as a prediction equation can lead to very large errors.

When a complex physical situation is involved, rather than attempting to use an inadequate model and inserting empirical coefficients, it may be better to derive empirical equations in the first place and let the data

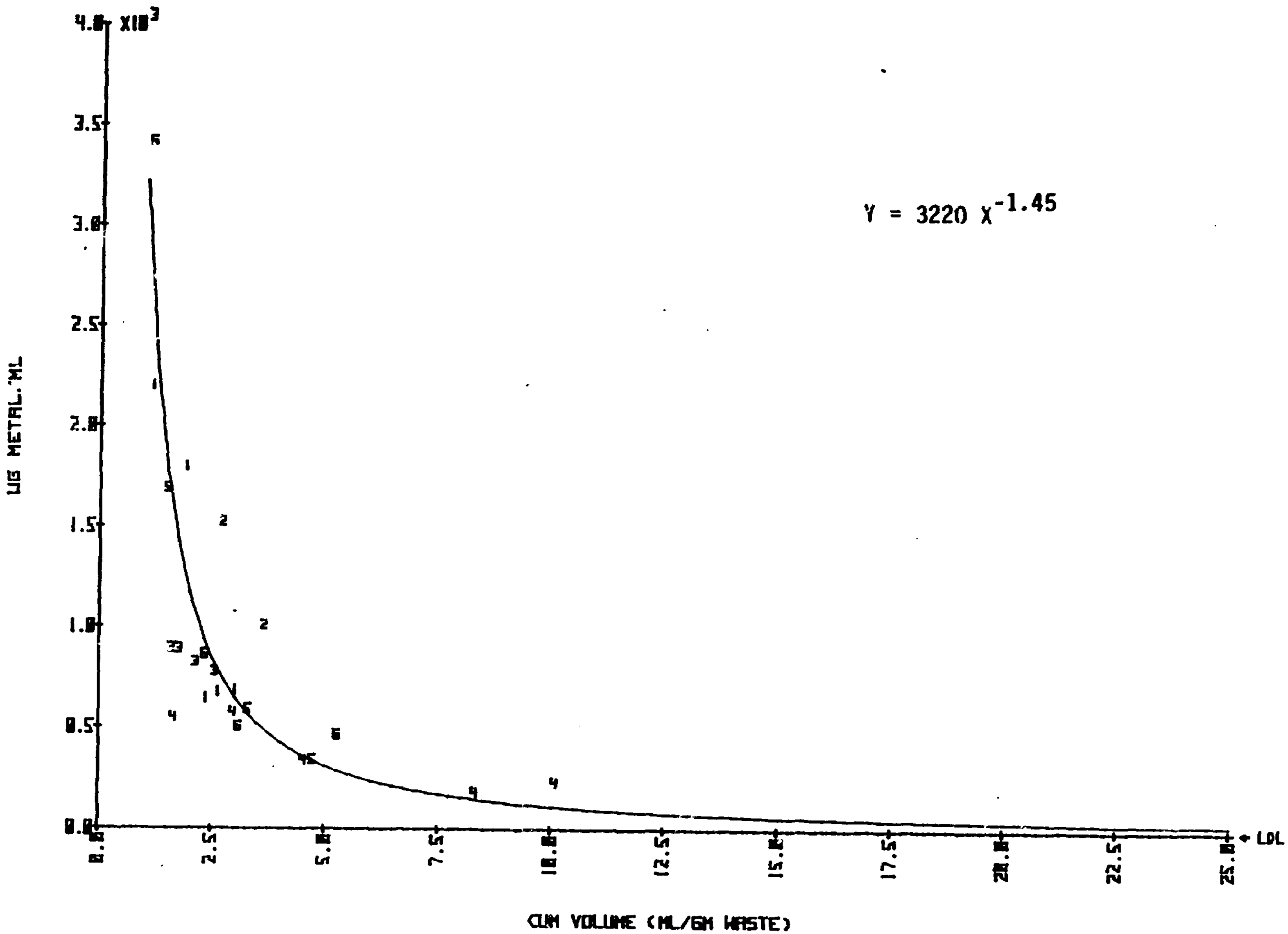


FIGURE 15. CADMIUM LEACHED FROM Ni-Cd BATTERY WASTE BY WATER.[1]

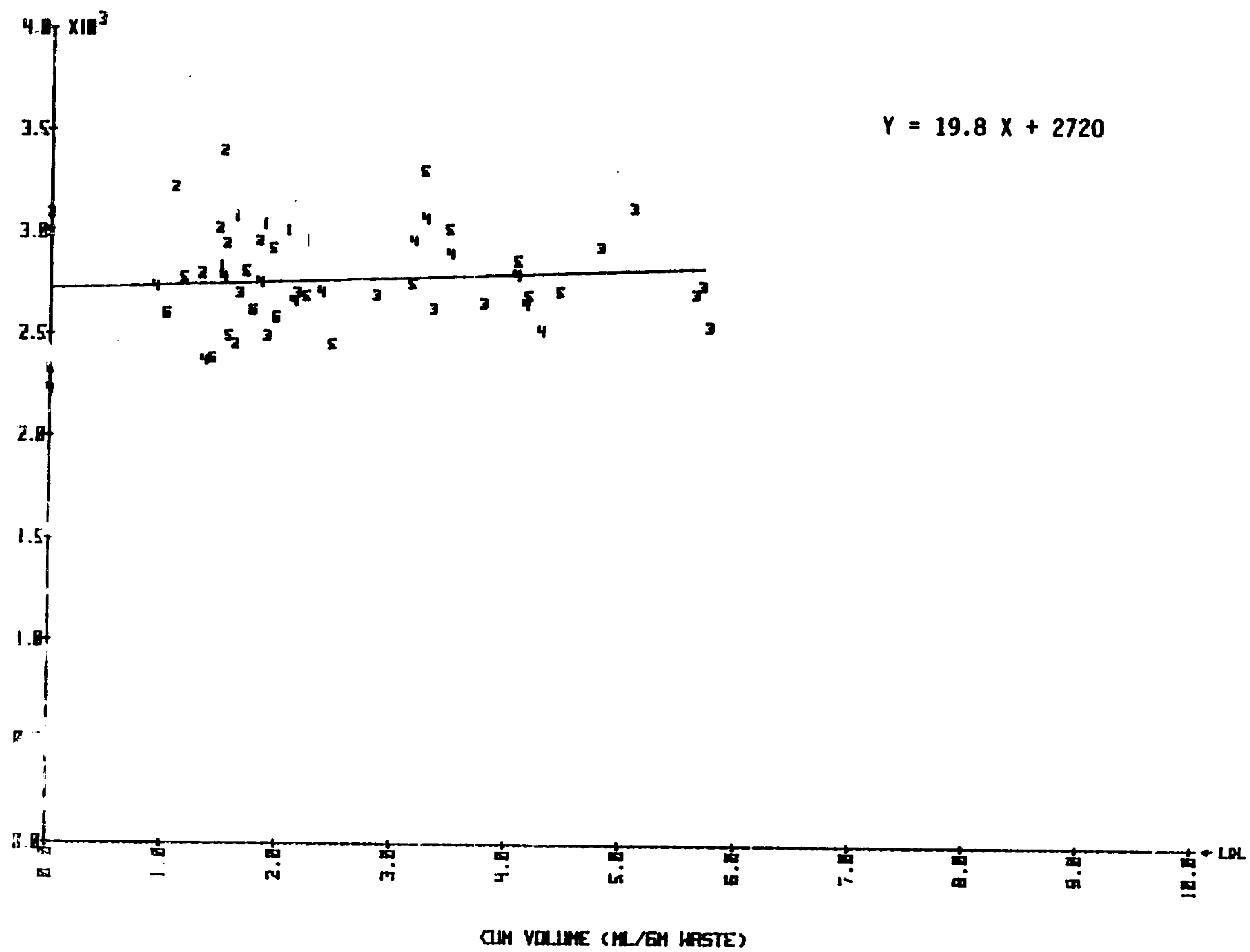


FIGURE 16: CADMIUM LEACHED FROM Ni-Cd BATTERY WASTE BY LANDFILL LEACHATE.(1)

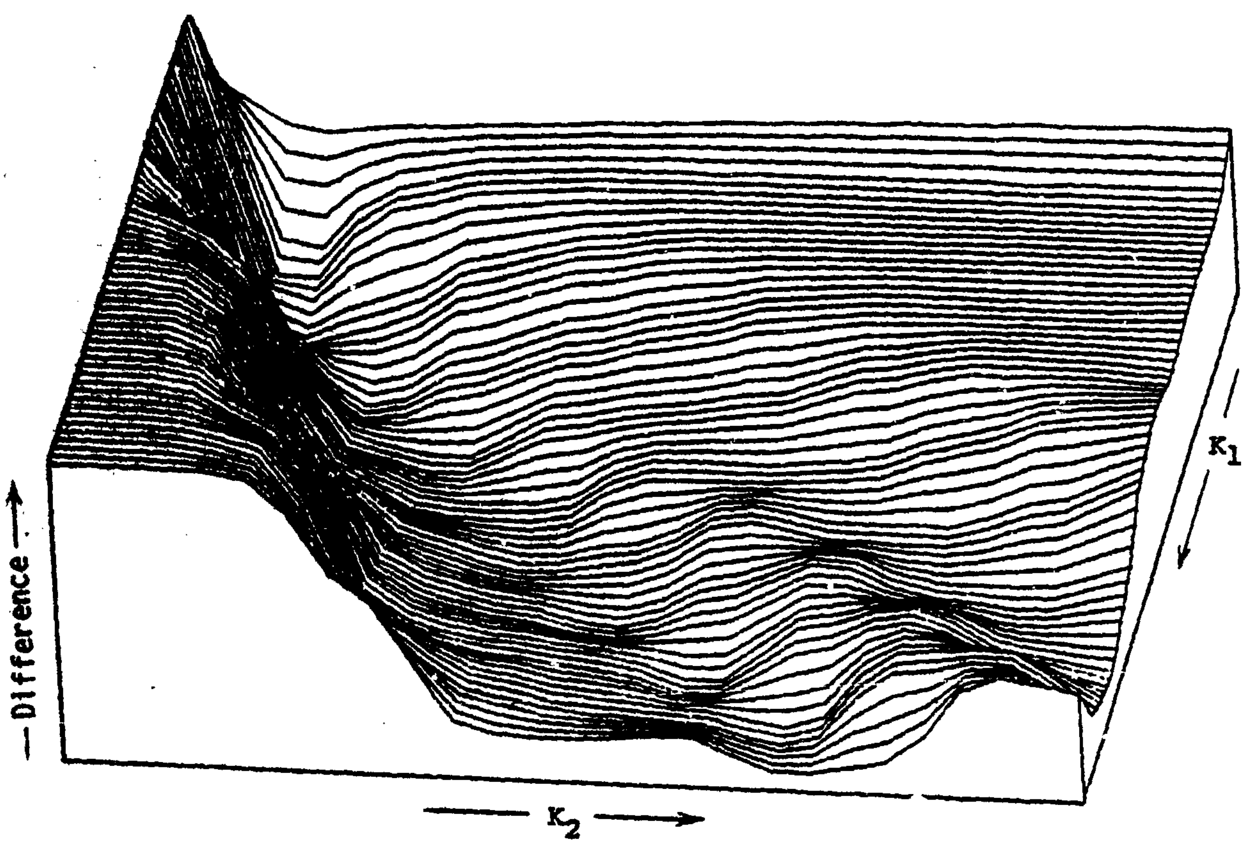


FIGURE 17. SURFACE SHOWING DIFFERENCE BETWEEN MODEL AND EXPERIMENTAL DATA.[22]

speak for itself. A modeler needs to understand and define everything of significance about a system whereas the developer of an empirical equation does not. Eventually it may be possible to obtain good models which define the movement of ions through soils, but at present the quickest route to valid prediction equations is most likely through equations that are entirely empirically derived.

Empirical Equations

If the interest in obtaining equations which describe a complex system is not for theoretical purposes but is for practical applications like predicting a response resulting from known levels of given variables, then obtaining purely empirical equations should be a more straight-forward approach. But caution is still required if the equations are to describe a field situation. Equation parameters should be derived from experiments that include all of the factors having significant effects. The design of the experiment should be such that the scope of its applicability and its relation to an actual field situation will minimize the number of assumptions needed in the corresponding prediction equations. This will improve the validity of the predictions. For example, the changes in K reported in Section 6 show that the experiments should employ an actual changing waste leachate so that predictions will not have to be based on the assumption of a constant composition or so that the nature of the changes will not have to be assumed. The closer the laboratory simulation approaches a field situation, the fewer additional assumptions that will have to be applied and the more reliable the predictions likely will be. Rapid experimentation which is flexible enough to simulate each new field situation even makes case-by-case experimental determinations practical, thus reducing to a minimum the dependence upon the ability of an equation to extrapolate.

It is our opinion that mathematical models should not be introduced too soon in an attempt to construct an expression meant to predict the behavior of a complex system. Experimental examination of the effects of impressed variations can (if the experiments are suitably designed) take into account the effect of unidentified (unknown) factors. Afterward, in the application of these results, mathematical compensation may be introduced to correct for those factors which were not included in the experimental set-up (such as upward capillary flow, horizontal spreading, etc). Additional experimentation may be required to quantitate these effects. The final description of the predictions should be in a mathematical framework which yields output weight or concentration in terms of time, volume, etc., upon plugging in values for all factors which differ from those employed in the experimental determinations or those effects which otherwise need correction (like experiments on a saturated system being applied to predictions on unsaturated).

In this connection, some comments are in order concerning the nature of the proposed graded serial batch extraction procedure:

a. Batch extractions are considered to be of zero dimensionality. (23) The batch extraction method _is_ independent of soil dimension in one sense, but the relation employed in the design of the experiments reported here yields results expressed per unit volume of soil, i.e., in three-dimensional

space. In the application of these results to the field, the effect of horizontal spreading (how the space occupied by the volume changes with time) can be taken into account.

b. Even though an extraction can be classified as static with respect to liquid-front movement, the sequential extractions proposed here simulate a stepped dynamic situation so a steady state need not be assumed for prediction equations in which these data are applied. The proposed batch extraction experiments thus should provide very useful input data for a variety of transport models. (Predictions are better based on laboratory simulations than upon completely mathematical "simulations".) Additional soil batches (i.e., more than three) could be used to better define what happens with increasing penetration depth into the soil.

c. The serial batch experiments provide direct information for saturated-only transport models. Corrections must be inserted if there is a significant difference caused by unsaturation. (Comparison between batch and column showed no difference for most ions studied.) (2) The rate of movement could also differ greatly without causing significantly different adsorption equilibria, i.e., the K values may be sufficiently alike so long as equilibrium is attained.

d. The calculated time equivalencies listed in Table 12 are for the idealized case of a uniformly-packed bed of soil (similar to that prepared in a column or for a lagoon lining). Inhomogenities in composition (such as steaks of sand in a bed of clay) or fissures produced by, e.g., rotted roots, will not only greatly increase the liquid front velocity in those zones but the resulting channeling can significantly reduce the effective mass of soil contacted by the waste extract. For example, if channeling is bad, 70 percent of the liquid may leak through and contact but a small fraction of the soil, while only the remaining 30 percent of the waste leachate would be available to percolate through the bulk of the soil. Corrections can be readily included for this kind of deviation from ideality if their relative magnitudes can be estimated for the site of interest. Another situation that would affect the liquid-front velocity presumed for a given bed of soil, one which would require separate flow-rate columns to detect, is the case where the waste leachate itself affects the flow through the soil, either by plugging the pores and reducing the flow, or by affecting the soil structure and drastically increasing the flow-rate (this was observed with flue gas waste on Davidson soil (24)).

e. It is recognized that in the field very slow processes may contribute to the net retention or even change the conditions under which retention is occurring (like micro-biological modification of the leachates and/or soils). The relative net effect of the slow to the fast processes during the time of contact will determine their significance. If slow processes have a significant proportional effect, it may not be possible to accelerate the testing by reducing the contact time below the residence time calculated for a given liquid front velocity. However, it is also not desirable simply to wait for equilibrium to be established if this requires longer than the field residence time for a slug of liquid of a given composition.

A change in the distribution coefficient shows a shift in the equilibrium. The change in K could be plotted versus pH or hydrogen ion concentration, the concentration of other ions, or against the measured values observed or calculated for the slope, or other responses of concern could be regressed against the level of selected experimental factors to see if a simple relation exists between a response and a factor. (I.e., test for or derive a relationship between the measured or calculated parameters and the experimental variables.) But, it is necessary to be careful when drawing conclusions in this way. What is being done with the data to relate factors (variables) may be analogous to classical vary-one-factor-at-a-time experimentation. If so, the conclusions can be very far off if interactions existed between the factors being plotted or examined numerically. The only sure way to take interaction into account is to run the experiments as factorial experiments and then derive the relations between the statistically significant factors and interactions using regression analysis. The effect of many kinds of variables can be determined by relatively small perturbations superimposed upon the total simulated field conditions, as by using the method of additions to study the effect of the concentration of Ca^{++} or other ions. Other factors, like temperature, surface area, soil type, etc., can be readily included. A number of factors can be included simultaneously with factorial experiments. (Models might be of help to point out possibly-important factors that should be included in the experiments, but mental imagery, not mathematical formulations, ultimately provides the input for deciding what variables to include in experiments.) If the number of potential factors is large, it may be desirable to run screening experiments like main-effect factorial experimments first, possibly followed by fractional factorials.

Even with the best kind of designs, the magnitude of the effect of only those factors purposely varied can be learned from the experiment, but some other factors may have an effect and even interact with the experimental factors. But if any unidentified factors can be kept at the same levels as they occur in the field (such as by using the same soil throughout the experiment because some unknown soil properties may be significant factors), then the effect of the known factors will be correctly estimated even if interaction does exist between them and the unidentified factors.

SECTION 6

EVALUATION OF INDUSTRIAL WASTES

Samples of wastes were collected from a single plant in each of the following industries: zinc-carbon battery manufacturing, titanium dioxide pigment production, hydrofluoric acid manufacturing, white phosphorus production, zinc secondary-refining, and oil re-refining. These wastes (described in detail in Section 4) were examined for the water-extractibility of certain inorganic ions during a series of seven extractions (by usually redoubled volumes). This corresponded to an exposure to a water-source, such as atmospheric precipitation, for a period of time which can be estimated by the relation developed in Section 5, page 37. The resulting leachates were then applied, in sequence, to three batches (corresponding to three layers) of each of three different clay soils: Chalmers, Davidson, and Nicholson soil. Analysis of the solutions for pH, conductivity, and concentrations of specified ions before and after contact with the soils allowed observing the effect of a soil on the leachate, as well as seeing how later changes in the leachate affected the retention of an element on a soil. No attempt was made to investigate the mechanisms responsible for the soil and waste leachate interactions.

These wastes represented a reasonably wide range of characteristics for testing the graded serial batch extraction procedure — from very soluble to relatively insoluble, from extremely acidic to highly basic, and one was an organic waste. These practical applications provided data which could be presented in a variety of ways. The graphs and tables that were chosen for conveying the test results are included in the following subsections, each of which covers one of the wastes.

First, in the discussion portion of each subsection, a short table presents the leachability of the elements of interest in the waste. (Table 15 is an example.) The column labeled Initial Concentration refers to the concentration in the first extract. Next, the point in the series of extractions when the concentration in the extract levels off is identified. The equivalent leaching time is taken from Table 12 and is offered as a comparative index of the rate of leaching. The next column in Table 15 gives the total Weight of the Element Extracted per gram of waste. This is calculated up through the extraction prior to the one in which the lower detection limit (LDL) was reached or up through the seventh extraction if samples remained above the LDL. The last column in the table gives the percentage this weight represents of the total weight of an element in the waste (as reported in Section 4).

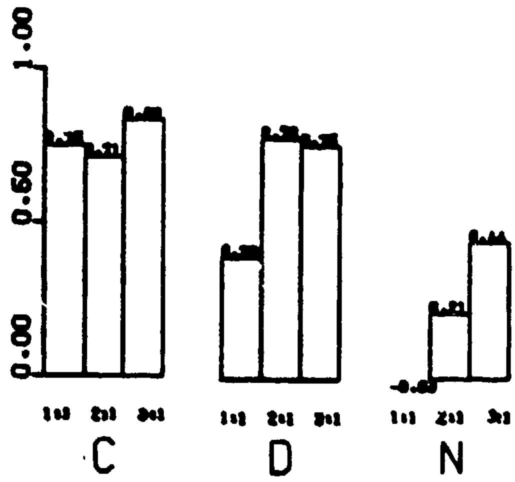
The bottom portion of these waste leachability tables gives the conductance and pH in the first and the seventh waste extracts. The specific conductance was measured for each sample because it is a convenient indicator of the solubilization of materials from a waste or soil. Multiplying the specific conductance by 0.01 yields an estimate of the number of microequivalents of dissolved solids per milliliter for many waters (25). Multiplying the microequivalents/milliliter by the sample volume gives the total microequivalents of dissolved ionic species present in the extract. The figure given in the table is the cumulative sum calculated from all seven extracts. Although its accuracy will vary depending upon the equivalent conductances of the mixture of ions present in the solution, this figure provides an estimate of the amount of waste that dissolved.

For each element of interest a graph was prepared showing its leachability from the waste. (See for example Figure 24.) The y-axis gives the concentration, micrograms/milliliter, of the element found in the extract (be sure to note whether an exponent is given). The cumulative volume scale on the x-axis is accompanied by a scale giving the calculated correlation with time, showing the equivalent number of years of exposure to a source of water which is moving through the waste into the underlying soil at a pore water velocity of 1×10^{-5} cm/sec. The lower detection limit for the assay is indicated to the far right for guidance in evaluating the significance of the histogram bar height. Above the histogram bar is printed the total weight of the element liberated by that extraction. This is expressed as micrograms per gram of waste, which is equivalent to grams per metric ton of 2204.6 pounds. If and when the lower detection limit is reached, no weight is given because the results in this region are undefined: they can be anywhere in the range from zero to the weight calculated from the detection limit.

Each waste characterization histogram is followed by a set of histograms (one for each extraction) which compares the fraction of that element retained from the waste leachate by the three soils for three different soil-to-waste ratios (1:1, 2:1, and 3:1). The height of the histogram bar and the value printed on it show the fraction retained from the cumulative total challenge up to the point represented by that extraction (calculated as in column I, Table 13). If the soil gives up that element, then the negative value is printed under the space corresponding to the appropriate layer of soil. The soils are designated by the letters C for Chalmers, D for Davidson, and N for Nicholson soil.

For example, the results of taking the leachate from the sixth extraction of waste zinc-carbon batteries and challenging the soil batches that had already been subjected to five previous extractions of waste leachate are given in the following portion of Figure 25:

6.

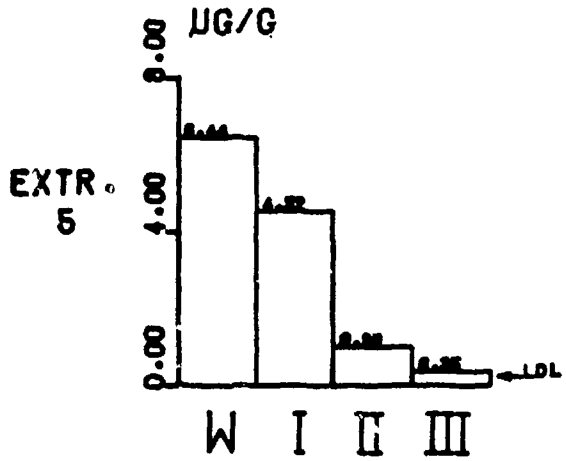


The first bar in the first histogram shows that 75 percent of the cadmium present in the six extracts had been retained by Chalmers soil at a 1:1 soil-to-waste ratio. (Table 16 shows that the fraction retained from this sixth extraction was -0.22, meaning that the soil was starting to lose previously held cadmium, although the cumulative net fraction retained was still 0.75.) The solution exiting this first batch of soil can be different from the solution that entered it in many ways, and the cadmium concentration was 0.80 µg/g instead of 0.65 µg/g, a difference of 0.15 µg/g. When this resulting solution was placed on the second batch of soil, a total of 71 percent of the cadmium was removed by passage through what is now a 2:1 soil-to-waste ratio. This means that the different sample matrix caused a loss of even more of the cadmium already on the soil. (Table 16 shows that the fraction retained from the total challenge to soil batch II up through extraction 6 is -0.15, a loss of 1.42 µg/g cadmium.) Be aware that the fractions found in these experiments strictly apply only for the wastes studied and for the concentration level and total quantity of that element present in these tests. Extrapolation could lead to erroneous conclusions.

Following the above-mentioned waste characterization curves and the summarizing soil-retention histogram is a series of tables and graphs that detail, for each kind of soil, the results obtained for each element extracted from a waste. A table of values calculated from the batch extraction data in the manner shown in Table 13, page 42, is presented for each soil. On each page facing a table is a set of histograms that give the weight, micrograms per gram waste or soil, of element observed in the extracts from the waste (designated by histogram bar W) and from each batch of soil (I, II, III) for each of the seven extractions. This latter histogram thus shows the amount of element penetrating or released from the soil as discussed in Section 5. (Refer to Figure 13, page 44, for the significance of the histogram bars.) The analytical detection limits are indicated to the right of the histogram, but here they are expressed in terms of micrograms per gram of waste or soil to be consistent with the units on the histogram. (The liquid-to-solid ratio was kept the same for W, I, II, and III so that results could be expressed as micrograms per gram of either waste or soil.) Because the detection limits are expressed as a weight of element per weight of waste or soil, they increase with each succeeding extraction because increasing volumes of solution are used to extract a fixed weight of waste or soil. For this same

reason the histogram bar height will increase as the extraction proceeds, for the case when the output concentration becomes constant, because a given concentration in a larger volume represents a greater weight. So take note that these soil histograms are expressed in terms of weight of element per unit weight of waste or soil. The corresponding concentrations in micrograms per milliliter can be obtained from the accompanying tables.

To show the source of the numerical values on this kind of histogram, a portion of Figure 27 is given as an example:



The histogram identified as EXTR. 5 in Figure 27 shows that the 5th time the same sample of zinc-carbon battery was extracted, the solution from W contained 6.44 micrograms cadmium per gram of waste. This solution was mixed with the first batch (I) of Davidson soil. (A flowchart of the serial batch extraction procedure is shown in Figure 2 for the first two extractions.) When the solution was filtered, it contained 4.52 micrograms cadmium per gram of soil contacted by the solution; the difference between W and I had been retained by the soil. The solution filtered from soil batch I was mixed with soil batch II for a predetermined length of time. After filtering II, analysis of the filtrate showed that soil batch II had reduced the solution concentration to 0.98 micrograms cadmium per soil contacted. This corresponds to the concentration penetrating a second layer of soil. The difference, 4.52 minus 0.98, or 3.54 micrograms cadmium per gram, was retained by the soil. The solution from II was mixed with soil batch III and the solution concentration of the resulting filtrate was 0.35 micrograms cadmium per gram, only slightly above the lower detection limit (←LDL) of the analytical method. Of the initial 6.44 micrograms cadmium per gram in the fifth extract, only 0.35 micrograms cadmium per gram penetrated (i.e., was not retained by) the three soil batches. The weights of waste and soil were chosen so that this corresponds to the penetration through the amount of soil equivalent to a 3:1 soil-to-waste ratio.

Although analytical variations will be responsible for some of the differences within sequences, as explained in Sections 1 and 5 the progressing waste extraction and the passage of the resulting solution through the

soil continually changes the solution environment and the soil. Thus, what happens in one batch is not necessarily an indication of what to expect in the next. This unpredictability is expressed by the plot of isotherm segments shown in Figure 14. In many cases a chromographic type "peak" can be clearly seen to move through soil batches I, II, and III. In other cases the peak remains "submerged" and is discernable only as a wave of lowered retention progressing through the soil as the extractions are continued. To simplify the presentation of information, mainly the results from the 3:1 soil-to-waste ratio will be discussed. This uses the concentrations exiting soil batch III and the fraction retained of the total challenge which was calculated for the row designated as I + II + III.

The descriptive terms used in the following discussion will adhere to the guidelines presented in Table 14. Multiples of the proposed safe drinking water standards (SDWS) (26) or the safe irrigating water standard (SIWS) (27) are used as a point of reference to facilitate describing the magnitude of the concentrations of an element found in a sample.

TABLE 14. TERMS USED TO DESCRIBE THE MAGNITUDE OF ELEMENT CONCENTRATION IN LEACHATES.

Term	Very Low	Low	Moderate	High
Level	SDWS	10 X SDWS	100 X SDWS	1000 X SDWS
Element	Concentration, μg/ml			
Be	0.1*	1.	10.	100.
B	0.75*	7.5	75.	750.
Cd	0.01	0.1	1.	10.
Cr	0.05	0.5	5.	50.
Cu	1.00	10.	100.	1000.
F	1.8	18.	180.	1800.
Pb	0.05	0.5	5.	50.
Hg	0.002	0.02	0.2	2.
Ni	0.2*	2.	20.	200.
Zn	5.00	50.	500.	5000.

*SIWS

ZINC-CARBON BATTERY WASTE

The batteries used for these tests were reject, heavy-duty size D cells which had been passed between rollers before disposal to crack them open and expose the interior. Entire cracked batteries were used so as not to further increase the surface area but this meant that only four batteries were included in the sampling. These batteries could have been rejected by the manufacturer because they contained the wrong proportions of some component and therefore may not be representative of this type of battery. The batteries tested were moderately corroded. A more advanced state of corrosion could be expected to increase the solubility of the affected materials.

Table 15 summarizes the leachability of the waste heavy-duty zinc-carbon batteries. The percentage extracted was not calculated for any of the elements except zinc because the proportions given in Table 10 were an industry-wide average and can differ greatly in individual proprietary formulations (28).

TABLE 15. LEACHABILITY OF ZINC-CARBON BATTERY WASTE.

Element	Initial Conc. (μg/ml)	When Concentration Levels Off				Total Weight Extracted (μg/g waste)	Percentage Extracted
		Conc. (μg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days		
Cd	3.8	0.08	7	190	620	29.	--
Pb	0.27	0.1(LDL)	2	5	16	0.54	--
Hg	0.96	0.01(LDL)	3	11	36	2.1	--
Zn	170.	1.3	7	190	620	820.	22.

Measurement	Initial	Final	Estim.Tot.Extr. (μ equiv/g)
Conduct. (μ mho)	32,800	77.	1350.
pH	7.8	6.5	--

The effect of the three soils on the specific conductance of the extract was nearly identical, as can be seen from Figures 18 to 23. The conductance histograms show that a high proportion of the soluble materials penetrated the soils at first, but the output from both the waste and the soils soon dropped to a low level.

The pH of the waste extract dropped from 7.6 to 6.5 during the course of the seven extractions, which means that the hydrogen ion concentration increased 1.1 orders of magnitude, a factor of: antilog 1.1 = 12.6. The Chalmers and Davidson soil reduced the pH of the first extract to an average of 6.4, but the extract from the second and third batches of Nicholson soil averaged 4.6. By the seventh waste extract, none of the soils changed the pH much.

Cadmium

Figure 24 and the data in Tables 16, 17, and 18 show that Cadmium leached from these batteries to give a solution of moderately high (3.8 μg/ml) initial concentration. The concentration dropped exponentially to 0.08 μg/ml by the seventh extraction. The first extraction removed 7.7 μg cadmium/gram of batteries; a total of 28.7 μg cadmium/gram was leached out by the end of the series of seven extractions. The data in these tables, and the histograms of Figures 26, 27, and 28 show that the cadmium was well attenuated at first by Chalmers and Davidson soil but that all three soils later released some of the cadmium (signified by the minus signs in the tables) so that by the seventh extraction only 69 percent ot the total challenge was retained by Chalmers, 62 percent by Davidson, and 49 percent by Nicholson at a 3:1 soil-to-waste ratio. This is evident in Figure 25, which also gives a comparison of the three soils for all seven extractions at three different soil-to-waste ratios.

Lead

Lead was present in the battery leachate only in low concentrations: 0.27 μg/ml in the first extraction and it dropped to the detection limit by the second extraction. The cumulative weight extracted was 0.54 μg/g. (See Figures 29 to 33 and Tables 19, 20, and 21) The waste extract did not flush significant amounts of lead off the soils; the extracts were in the region of the detection limit so the data cannot be used for further calculations.

Mercury

Mercury was observed in the first extraction (Figure 34, Tables 22, 23, and 24) in a moderately high concentration (0.96 μg/ml) compared to SWDS, but it rapidly dropped to the detection limit. A total of 2.1 μg mercury/gram was extracted in the first two extractions. Figure 35 shows that Chalmers was the best of these soils for retaining mercury for this extract. Figures 36, 37, and 38 give results for the individual batches (layers) of soil.

Zinc

Zinc was present at a moderately low concentration (170 μg/ml) compared to SDWS in the initial extraction, as seen from Figure 39 and Tables 25, 26, and 27. The concentration dropped rapidly and reached very low levels by the fourth extraction. The total weight of zinc extracted in the seven extraction was 820 μg/g, which is 22 percent of the total available. Figures 41, 42, and 43 show the performance of the soils. The cumulative fraction retained graphed in Figure 40 show Chalmers and Davidson soils retained about twice as much zinc from this solution as did Nicholson soil.

Summary

In the leachate obtained by extracting broken zinc-carbon batteries with water, the initial concentrations of cadmium, lead, mercury, and zinc were low to moderately high compared to the safe drinking water standards. Their concentrations decreased as the leaching progressed and the effluent from the soils contained very low concentrations, although Nicholson soil retained less of each than did Chalmers and Davidson soil.

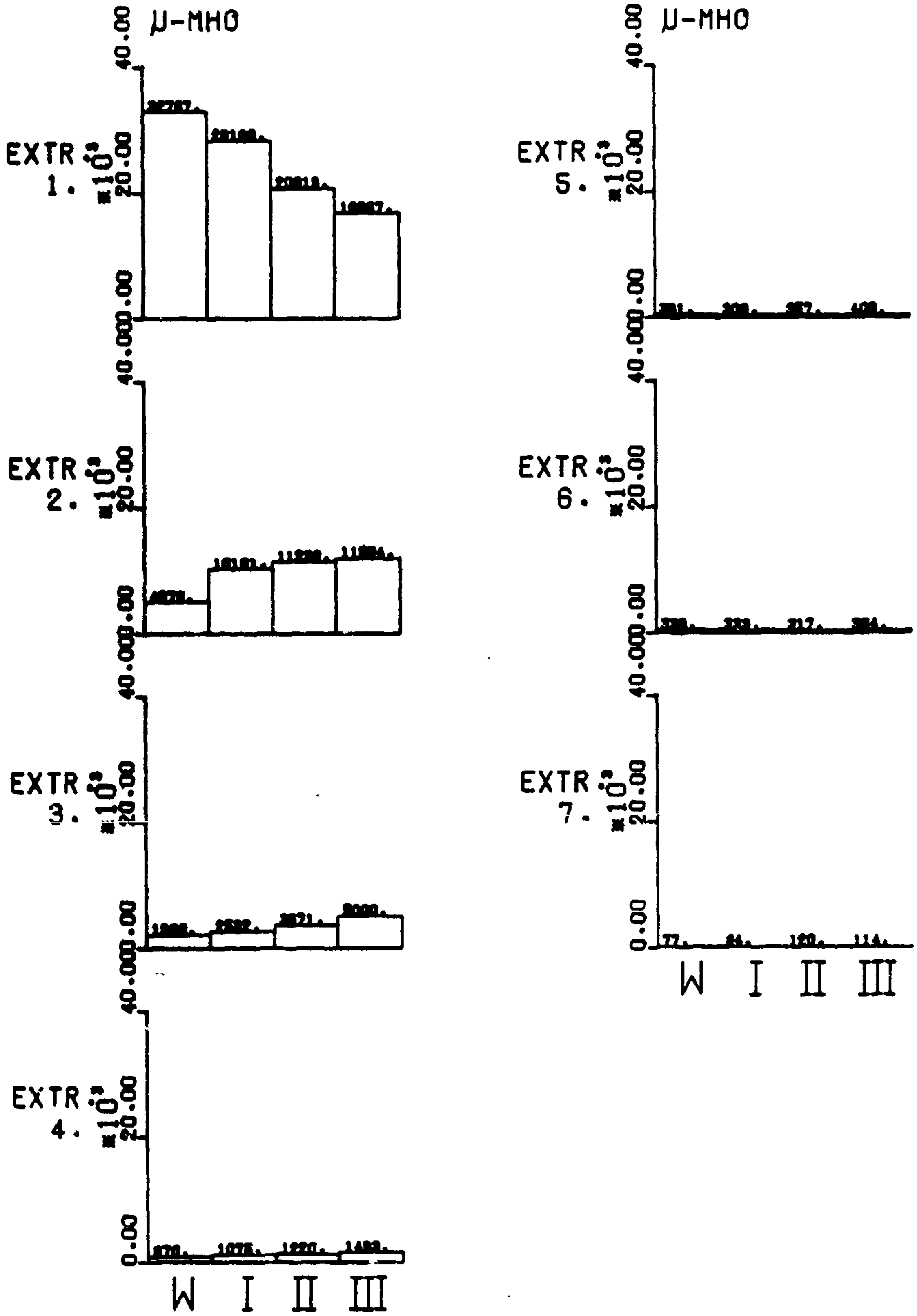


FIGURE 18. CONDUCTANCE OF EXTRACT FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

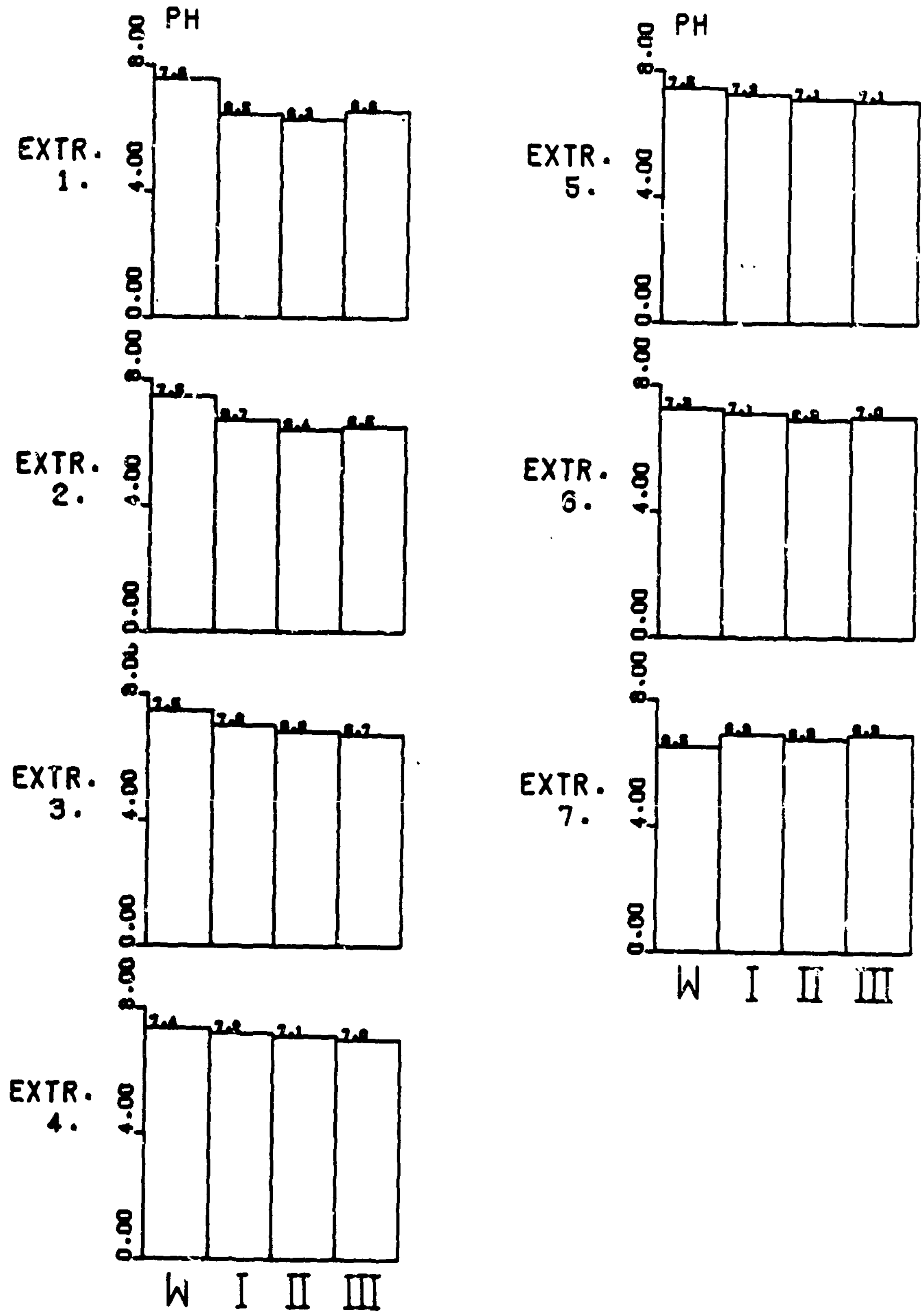


FIGURE 19. pH OF EXTRACT FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL

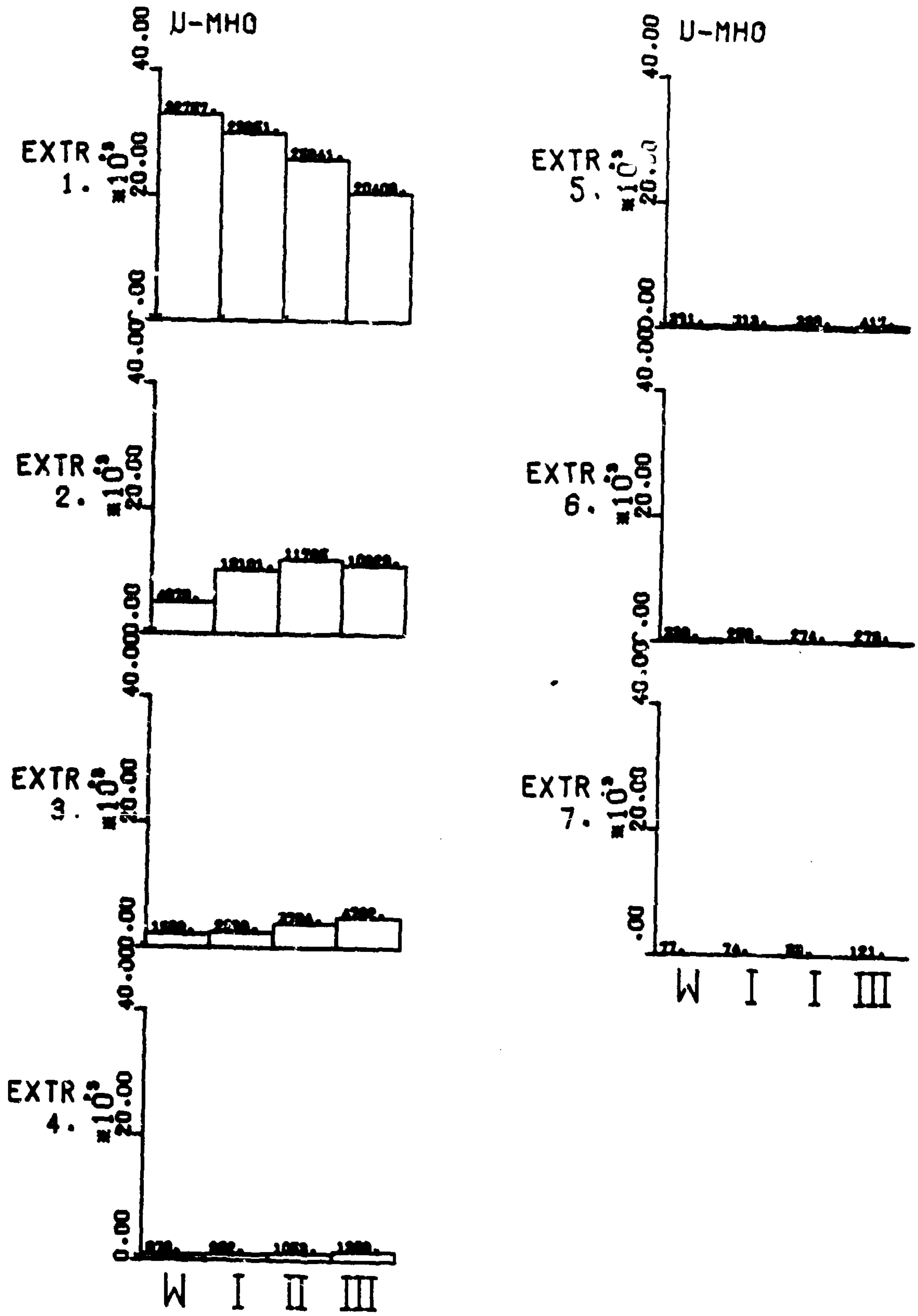


FIGURE 20. CONDUCTANCE OF EXTRACT FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

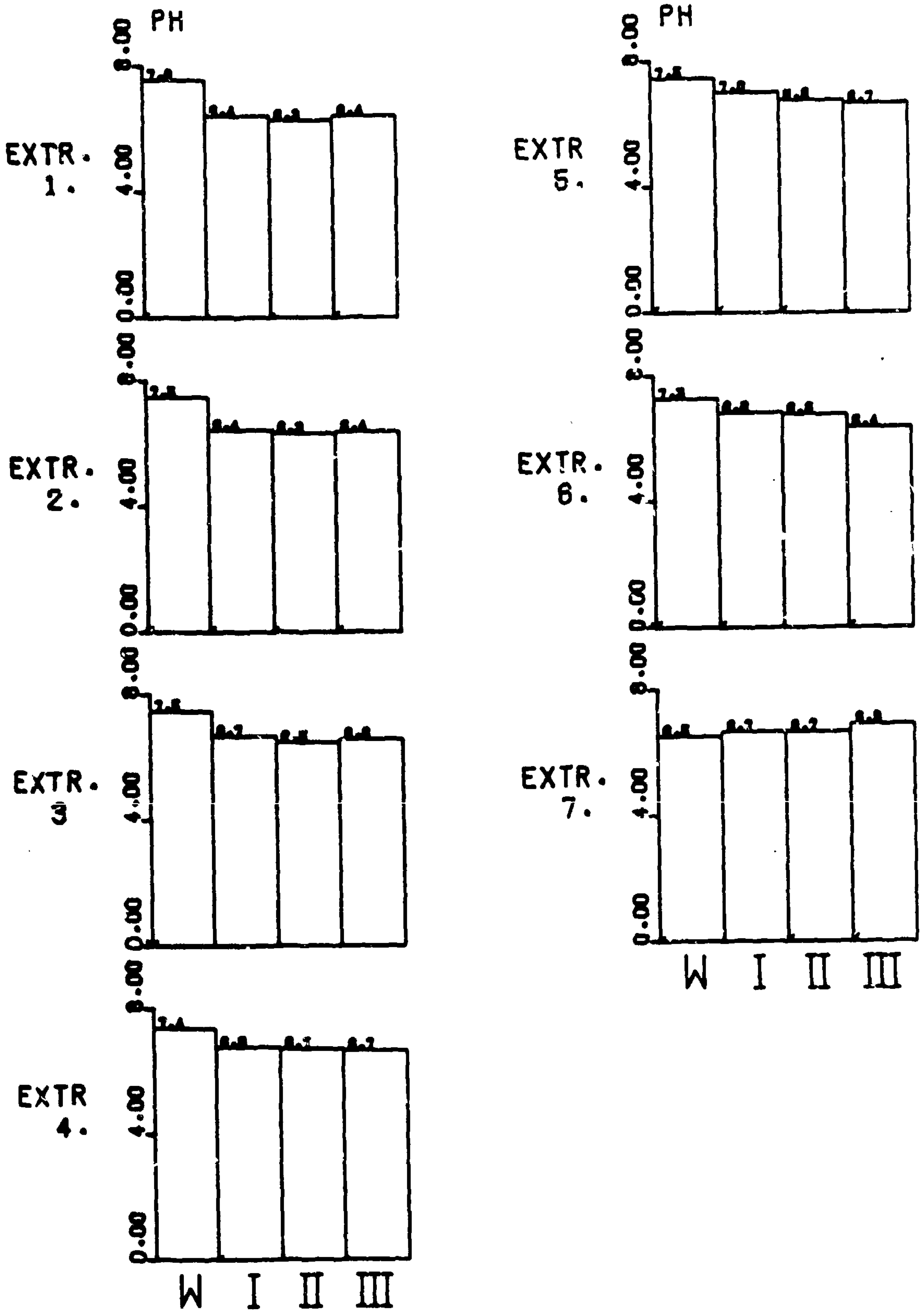


FIGURE 21. pH OF EXTRACT FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

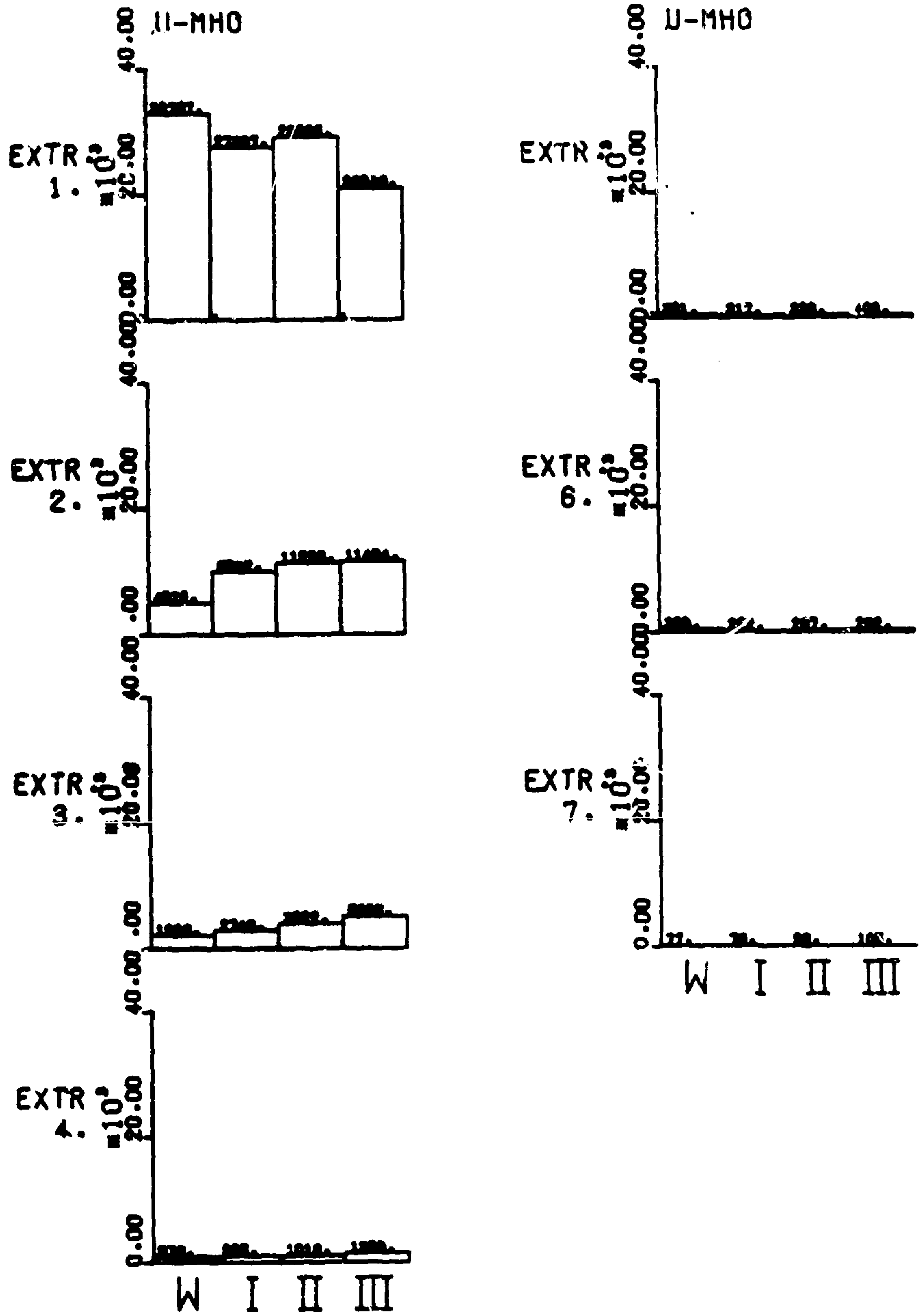


FIGURE 22. CONDUCTANCE OF EXTRACT FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

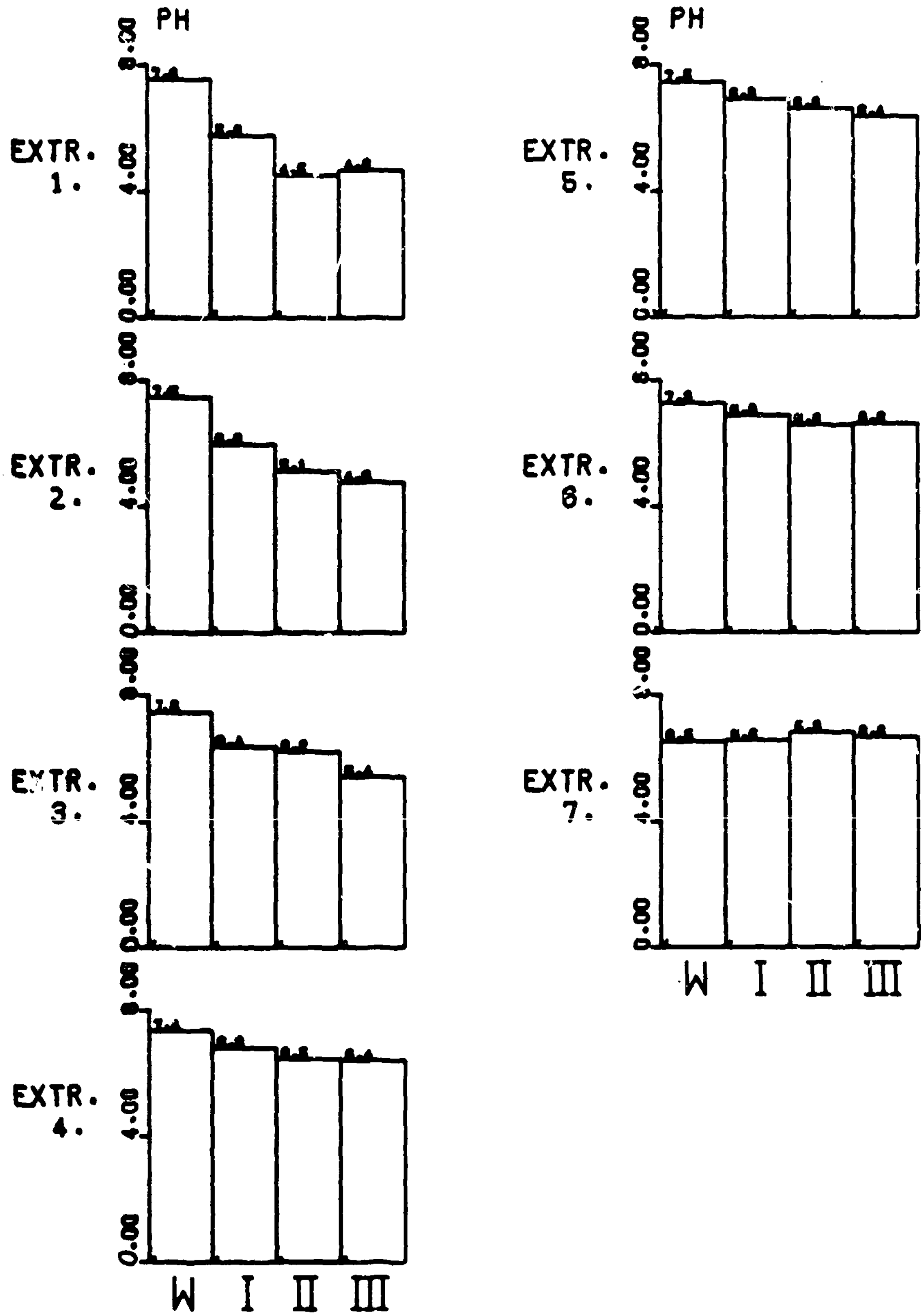


FIGURE 23. pH OF EXTRACT FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

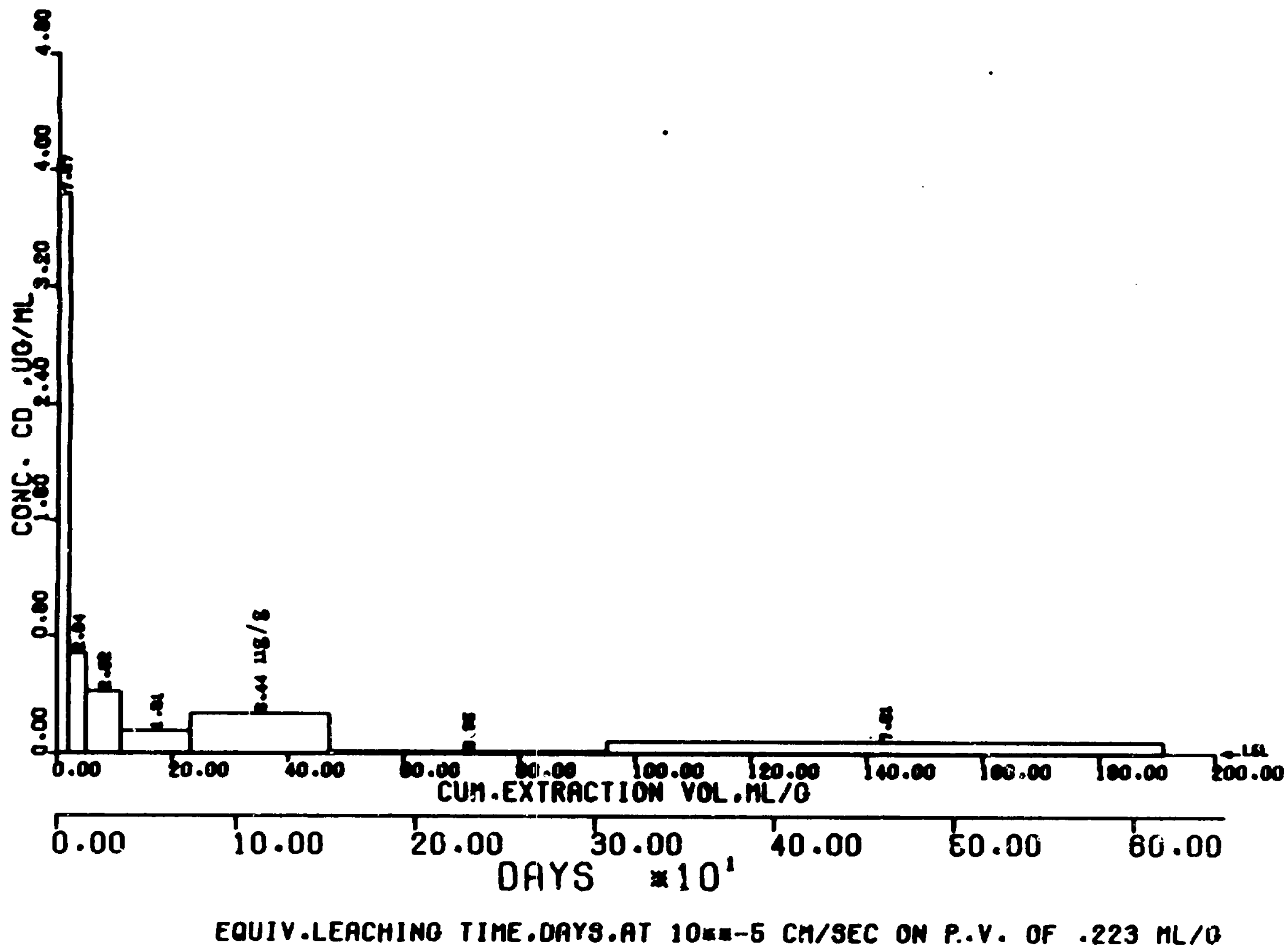


FIGURE 24. EXTRACTION OF CADMIUM FROM ZINC-CARBON BATTERY WASTE.

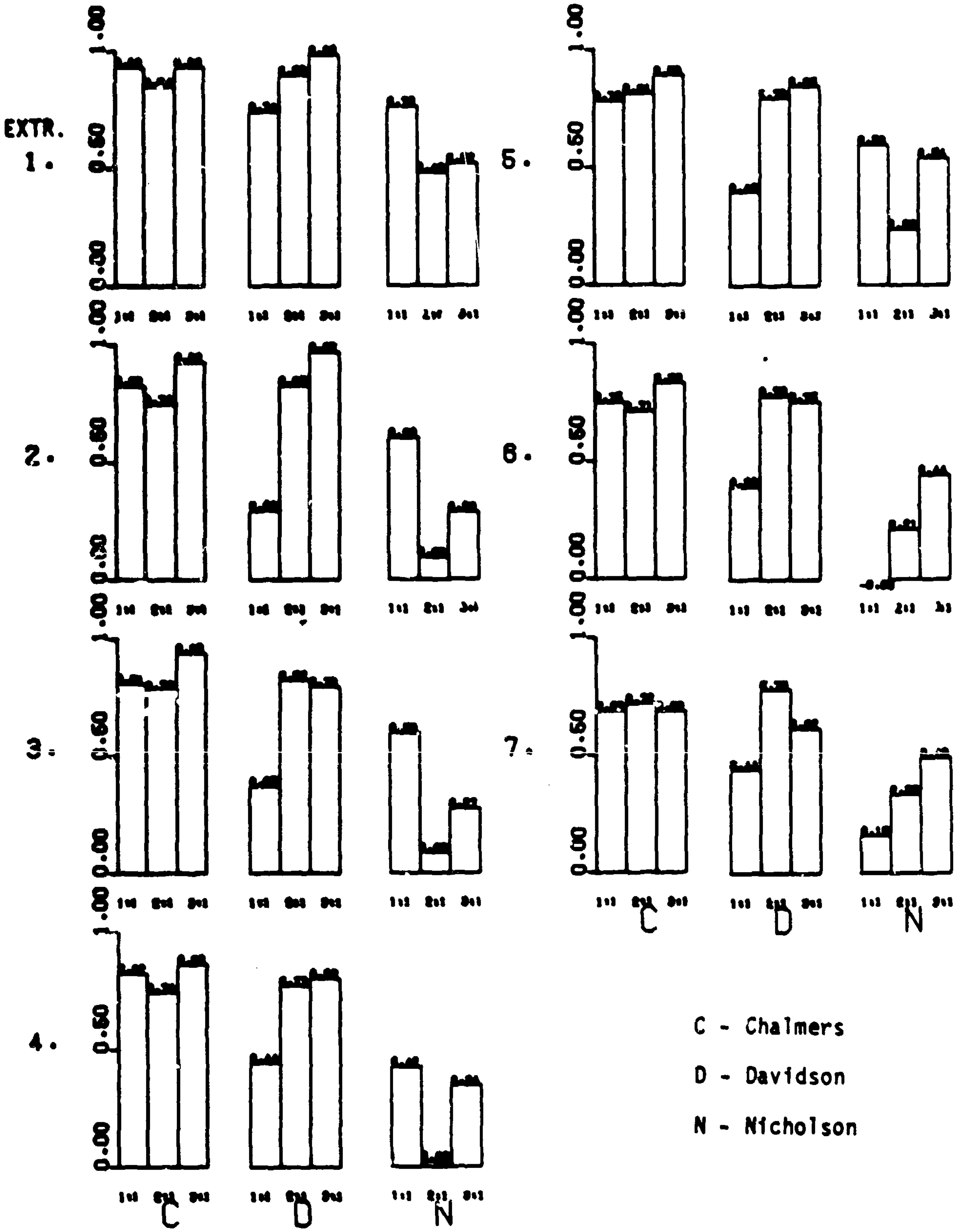


FIGURE 25. COMPARING FRACTION CADMIUM RETAINED BY SOILS FROM ZINC-CARBON BATTERY WASTE LEACHATE.

TABLE 16. CADMIUM FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	3.03	7.67										
	I	.27	.55	7.12	7.67	7.12	.93	.93	.07	13.94	85.90	13.03	85.61
	II	.60	1.19	-.65	.55	-.65	-1.10	-1.10	2.10	-.12	-7.00	-.54	-20.45
	III	.27	.54	.65	1.19	.65	.54	.54	.46	2.12	64.70	1.20	50.08
	I+II			3.24	3.03	3.24	.84	.84	.16	7.10	81.99	5.43	79.56
	I+II+III			2.37	2.56	2.37	.93	.93	.07	21.39	87.32	13.11	85.64
2	W	.60	2.04										
	I	.39	1.10	.05	9.70	7.97	.42	.02	.50	7.17	82.06	6.75	81.57
	II	.43	1.29	-.10	1.73	-.75	-.09	-.43	1.09	-.20	-11.04	-.50	-30.20
	III	.07	.20	1.09	2.40	1.74	.05	.70	.15	11.27	84.93	8.75	83.40
	I+II			.37	4.05	3.61	.37	.74	.63	7.17	82.06	5.62	79.90
	I+II+III			.61	3.23	2.99	.90	.92	.10	67.82	89.16	45.15	88.73
3	W	.42	2.52										
	I	.11	.64	1.00	12.22	9.85	.75	.81	.25	16.12	86.45	15.34	86.27
	II	.04	.23	.42	2.37	-.34	.65	-.14	.35	.73	35.85	-1.40	-55.91
	III	<.01	<.06	.17	2.71	1.90	.74	.70	.26	40.07	88.57	31.74	88.20
	I+II			1.15	6.11	4.76	.91	.78	.09	50.68	88.87	41.00	88.63
	I+II+III			.82	4.07	3.81	.90	.93	.02	265.35	89.78	190.35	89.70
4	W	.15	1.01										
	I	<.01	<.12	1.69	14.03	11.54	.93	.82	.07	100.37	89.43	96.29	89.40
	II	.08	.92	-.00	2.49	-1.14	-6.69	-.46	7.68	-.69	-34.66	-1.23	-50.99
	III	.10	1.15	-.23	3.63	1.67	-.25	.46	1.25	1.89	62.10	1.45	55.40
	I+II			.45	7.02	5.20	.49	.74	.51	13.47	85.75	11.30	84.94
	I+II+III			.22	4.60	4.03	.36	.86	.64	14.40	86.03	10.49	84.56
5	W	.27	6.44										
	I	.08	2.01	4.42	20.47	15.97	.69	.78	.31	8.19	83.03	7.94	82.82
	II	<.01	<.24	1.77	4.50	.63	.00	.14	.12	4.73	78.06	2.65	69.30
	III	.01	.33	-.09	3.07	1.59	-.36	.41	1.36	6.30	81.09	4.95	78.35
	I+II			3.10	10.24	8.30	.96	.81	.04	77.51	89.26	69.18	89.17
	I+II+III			2.04	6.82	6.06	.95	.89	.05	69.34	89.17	55.59	88.97
6	W	.01	.65										
	I	.02	.80	-.15	21.13	15.82	-.22	.75	1.22	20.41	87.19	19.78	87.11
	II	.05	2.23	-1.43	5.30	-.80	-1.79	-.15	2.79	-.13	-7.54	-.36	-19.62
	III	.03	1.23	.95	6.10	2.53	.42	.42	.58	2.36	67.03	1.97	63.10
	I+II			-.79	16.56	7.51	-2.41	.71	3.41	7.64	82.54	6.74	81.56
	I+II+III			-.21	7.04	5.85	-.96	.83	1.96	17.17	86.67	13.67	85.82
7	W	.00	7.61										
	I	.04	3.73	3.30	20.74	19.70	.51	.69	.49	5.41	79.53	5.28	79.27
	II	.02	2.04	.70	9.04	.90	.45	.10	.55	.69	34.54	.44	23.88
	III	.06	5.48	-3.44	8.13	-.91	-1.69	-.11	2.69	-.07	-4.28	-.17	-9.43
	I+II			2.79	14.37	10.30	.73	.72	.27	11.10	84.85	10.12	84.36
	I+II+III			.71	9.58	6.56	.28	.69	.72	4.42	77.24	3.59	74.45

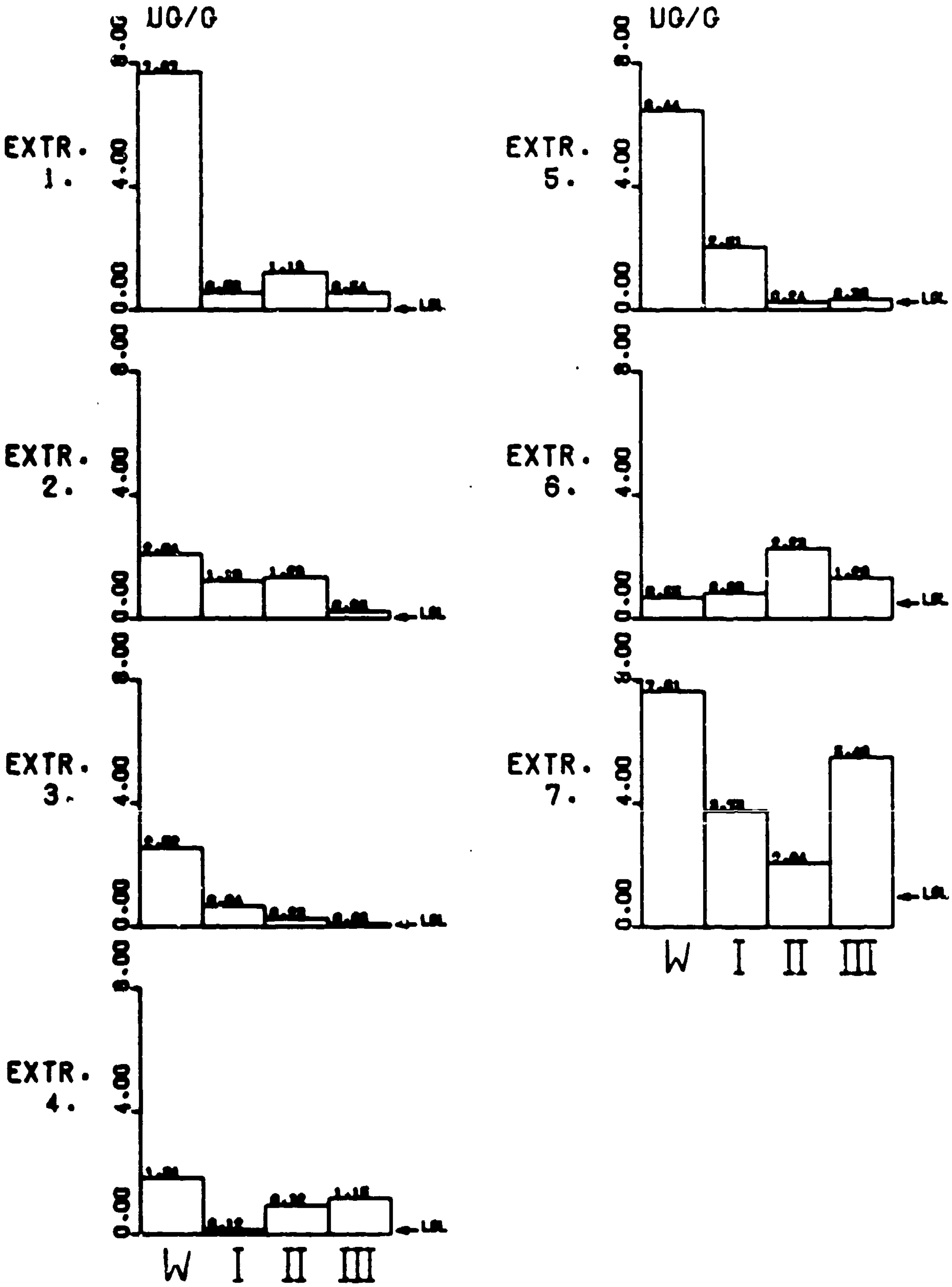


FIGURE 26. WEIGHT OF CADMIUM FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

TABLE 17. CADMIUM FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	3.83	7.67										
	I	1.00	2.01	5.66	7.67	5.66	.74	.74	.26	3.54	74.23	2.82	70.46
	II	.41	.81	1.20	2.01	1.20	.60	.60	.40	3.27	72.99	1.48	55.93
	III	.00	.16	.65	.81	.65	.81	.81	.19	13.34	85.71	4.14	76.42
	I+II			3.43	3.83	3.43	.89	.89	.11	15.62	86.34	8.46	83.26
	I+II+III			2.50	2.56	2.50	.98	.98	.02	130.48	89.56	47.65	88.80
2	W	.60	2.04										
	I	1.62	4.8[illegible]	-2.83	9.70	2.83	-1.39	.25	2.39	.00	41.34	.52	30.10
	II	.30	.91	3.96	6.87	5.15	.81	.75	.19	7.26	82.16	5.67	80.00
	III	.06	.17	.74	1.72	1.39	.82	.81	.18	16.91	86.62	8.29	83.12
	I+II			.56	4.85	3.99	.55	.82	.45	15.16	86.23	8.78	83.50
	I+II+III			.62	3.23	3.13	.92	.97	.08	133.36	89.57	55.76	88.97
3	W	.42	2.52										
	I	.14	.05	1.67	12.22	4.50	.66	.37	.34	7.02	81.89	5.31	79.33
	II	.00	.47	.30	7.72	5.54	.45	.72	.55	14.97	86.18	11.86	85.18
	III	.36	2.10	-1.72	2.19	-.32	-3.60	-.15	4.60	.52	27.25	-.15	-8.45
	I+II			1.03	6.11	5.02	.81	.82	.19	33.94	88.31	21.51	87.34
	I+II+III			.11	4.07	3.24	.13	.79	.87	10.42	84.52	4.45	77.32
4	W	.15	1.01										
	I	<.01	<.12	1.69	14.03	6.19	.93	.44	.07	63.70	89.10	51.62	88.89
	II	.09	1.04	-.92	7.04	4.62	-7.64	.59	0.64	5.86	80.31	4.46	77.36
	III	.02	.20	.75	3.22	.43	.73	.13	.27	6.59	81.37	1.50	56.20
	I+II			.39	7.02	5.41	.43	.77	.57	16.03	86.43	10.43	84.53
	I+II+III			.51	4.60	3.75	.84	.80	.16	85.28	89.33	39.46	88.55
5	W	.27	6.44										
	I	.19	4.52	1.91	20.47	8.11	.30	.40	.70	2.11	64.69	1.79	60.86
	II	.04	.90	3.54	12.36	8.16	.70	.66	.22	9.79	84.17	8.31	83.14
	III	.01	.35	.63	4.20	1.06	.64	.25	.36	7.13	82.02	3.01	71.61
	I+II			2.73	10.24	8.13	.85	.79	.15	22.48	87.45	16.57	86.55
	I+II+III			2.03	6.02	5.77	.95	.85	.05	86.42	89.34	49.29	88.84
6	W	.01	.65										
	I	<.01	<.40	.17	21.13	8.28	.27	.39	.73	20.28	87.18	17.26	86.68
	II	<.01	<.40	.00	12.04	8.16	.00	.64	1.00	20.02	87.14	17.00	86.63
	III	.04	2.04	-1.56	4.60	-.50	-3.24	-.11	4.24	.47	25.03	-.25	-13.70
	I+II			.09	10.56	8.22	.27	.78	.73	46.34	88.76	34.25	88.33
	I+II+III			-.46	7.04	5.31	-2.11	.75	3.11	14.24	85.98	7.83	82.72
7	W	.00	7.61										
	I	.03	3.25	4.36	20.74	12.65	.57	.44	.43	4.34	77.02	3.89	75.60
	II	.02	1.60	1.65	16 09	9.01	.51	.61	.49	7.04	81.91	6.13	80.73
	III	.06	5.07	-4.27	6.29	-4.77	-2.67	-.76	3.67	-.57	-29.47	-.81	-39.09
	I+II			3.01	14.37	11.23	.79	.78	.21	17.66	86.76	14.03	85 92
	I+II+III			.58	9.58	5.90	.23	.62	.77	5.24	79.20	3.02	71.65

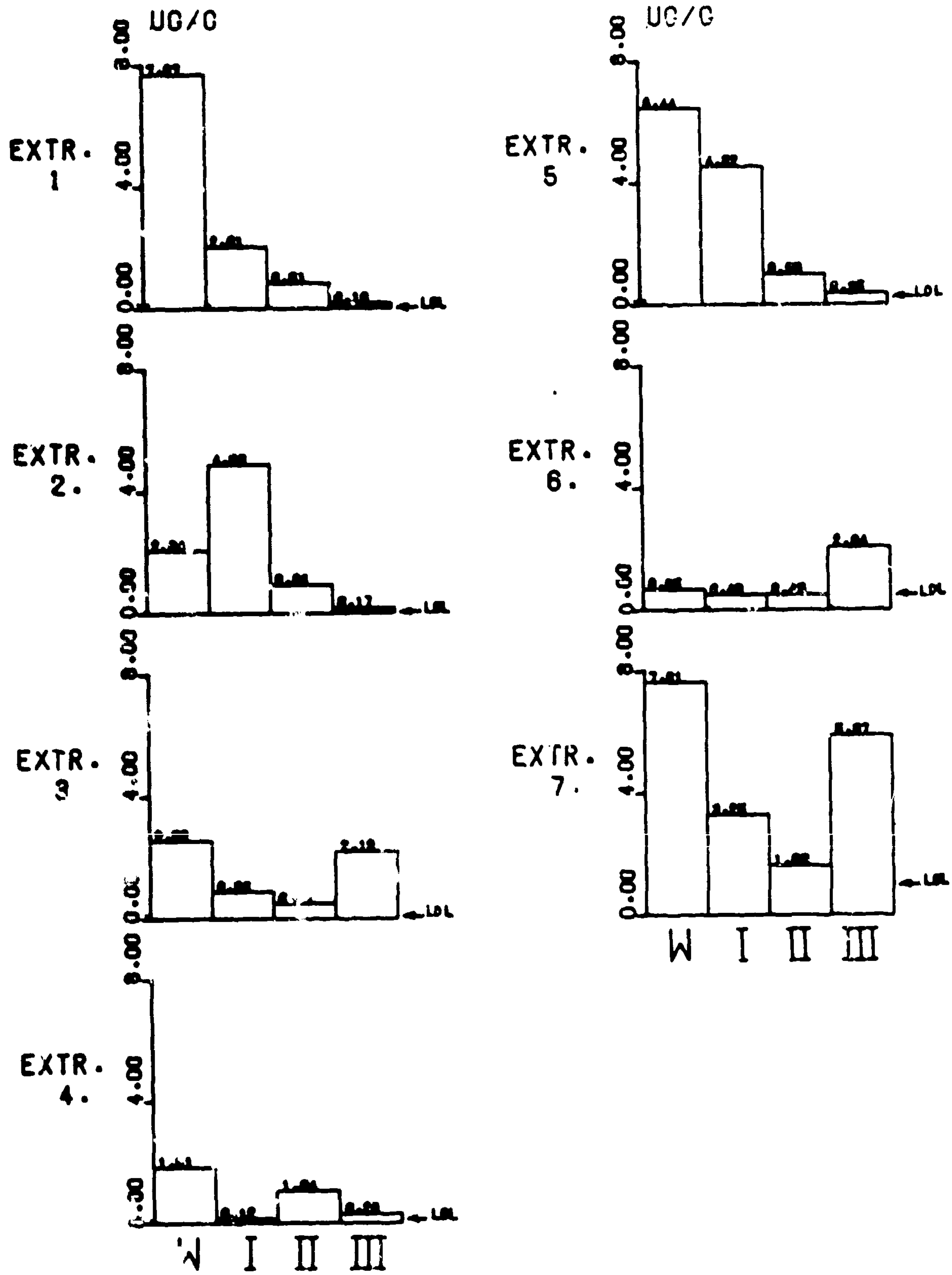


FIGURE 27 WEIGHT OF CADMIUM FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

TABLE 18. CADMIUM FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	3.83	7.67										
	I	.93	1.86	5.80	7.67	5.80	.76	.76	.24	3.38	73.54	3.12	72.21
	II	2.00	4.00	-2.14	1.86	-2.14	-1.15	-1.15	2.15	-.41	-22.26	-.53	-28.12
	III	1.05	3.71	.29	4.00	.29	.07	.07	.93	.21	12.07	.08	4.52
	I+II			1.83	3.83	1.83	.48	.48	.52	1.42	54.78	.92	42.51
	I+II+III			1.32	2.56	1.32	.52	.52	.48	2.28	56.34	1.07	46.89
2	W	.60	2.04										
	I	.60	2.03	.00	9.70	5.81	.00	.60	1.00	3.10	72.13	2.86	70.70
	II	1.61	4.82	-2.79	3.90	-4.92	-1.37	-1.26	2.37	-.72	-42.55	-1.02	-45.61
	III	1.09	3.26	1.56	8.82	1.85	.32	.21	.68	.72	35.85	.57	29.64
	I+II			-1.39	4.85	.44	-1.37	.09	2.37	.60	30.91	.18	10.41
	I+II+III			-.41	3.23	.91	-.60	.28	1.60	2.22	65.77	.84	40.05
3	W	.42	2.52										
	I	.10	1.00	1.45	12.22	7.25	.57	.59	.43	7.21	82.10	6.74	81.56
	II	.40	2.39	-1.31	4.97	-6.23	-1.22	-1.25	2.22	-2.40	-67.41	-2.61	-69.06
	III	.32	1.93	.45	11.20	2.30	.19	.21	.81	1.45	55.42	1.19	50.01
	I+II			.07	6.11	.51	.05	.08	.95	1.27	51.72	.43	23.10
	I+II+III			.20	4.07	1.11	.23	.27	.77	4.05	76.12	1.72	59.83
4	W	.15	1.01										
	I	.26	3.13	-1.32	14.03	5.93	-.73	.42	1.73	2.05	64.02	1.89	62.15
	II	.21	2.55	.59	8.10	-5.64	.19	-.70	.81	-2.02	-63.67	-2.22	-65.72
	III	.03	.32	2.23	13.75	4.53	.88	.33	.12	15.98	86.42	14.39	86.03
	I+II			-.37	7.02	.14	-.40	.02	1.40	.90	41.95	.11	6.45
	I+II+III			.50	4.68	1.61	.83	.34	.17	29.58	98.06	15.30	86.26
5	W	.27	6.40										
	I	.01	.24	6.20	20.47	12.13	.96	.59	.04	52.61	88.91	50.53	88.87
	II	.00	1.95	-1.71	8.34	-7.35	-7.13	-.08	8.13	-3.51	-74.11	-3.77	-75.14
	III	.01	.20	1.67	15.70	6.21	.86	.40	.14	24.06	87.62	22.27	87.43
	I+II			2.24	10.24	2.39	.70	.23	.30	3.47	73.93	2.45	67.76
	I+II+III			2.05	6.82	3.66	.96	.54	.04	55.53	88.97	39.39	88.55
6	W	.01	.65										
	I	.20	13.30	-12.73	21.13	-.60	-19.44	-.03	20.44	-.01	-.43	-.04	-2.57
	II	.02	1.04	12.34	21.72	4.98	.92	.23	.08	5.26	79.24	4.78	78.19
	III	.05	2.33	-1.28	16.74	4.92	-1.23	.29	2.23	2.33	66.77	2.12	64.70
	I+II			-.19	10.56	2.19	-.59	.21	1.59	6.13	80.73	4.21	76.63
	I+II+III			-.56	7.04	3.10	-2.56	.44	3.56	5.93	80.43	4.00	75.96
7	W	.08	7.61										
	I	.03	2.57	5.04	28.74	4.44	.66	.15	.34	1.92	62.53	1.73	59.96
	II	.03	2.47	.10	24.29	5.08	.84	.21	.96	2.26	66.11	2.05	64.05
	III	.03	2.91	-.44	19.21	4.49	-.18	.23	1.18	1.71	59.74	1.54	57.04
	I+II			2.57	14.37	4.76	.68	.33	.32	4.66	77.89	3.85	75.45
	I+II+III			1.57	9.58	4.67	.62	.49	.38	6.36	81.07	4.82	78.27

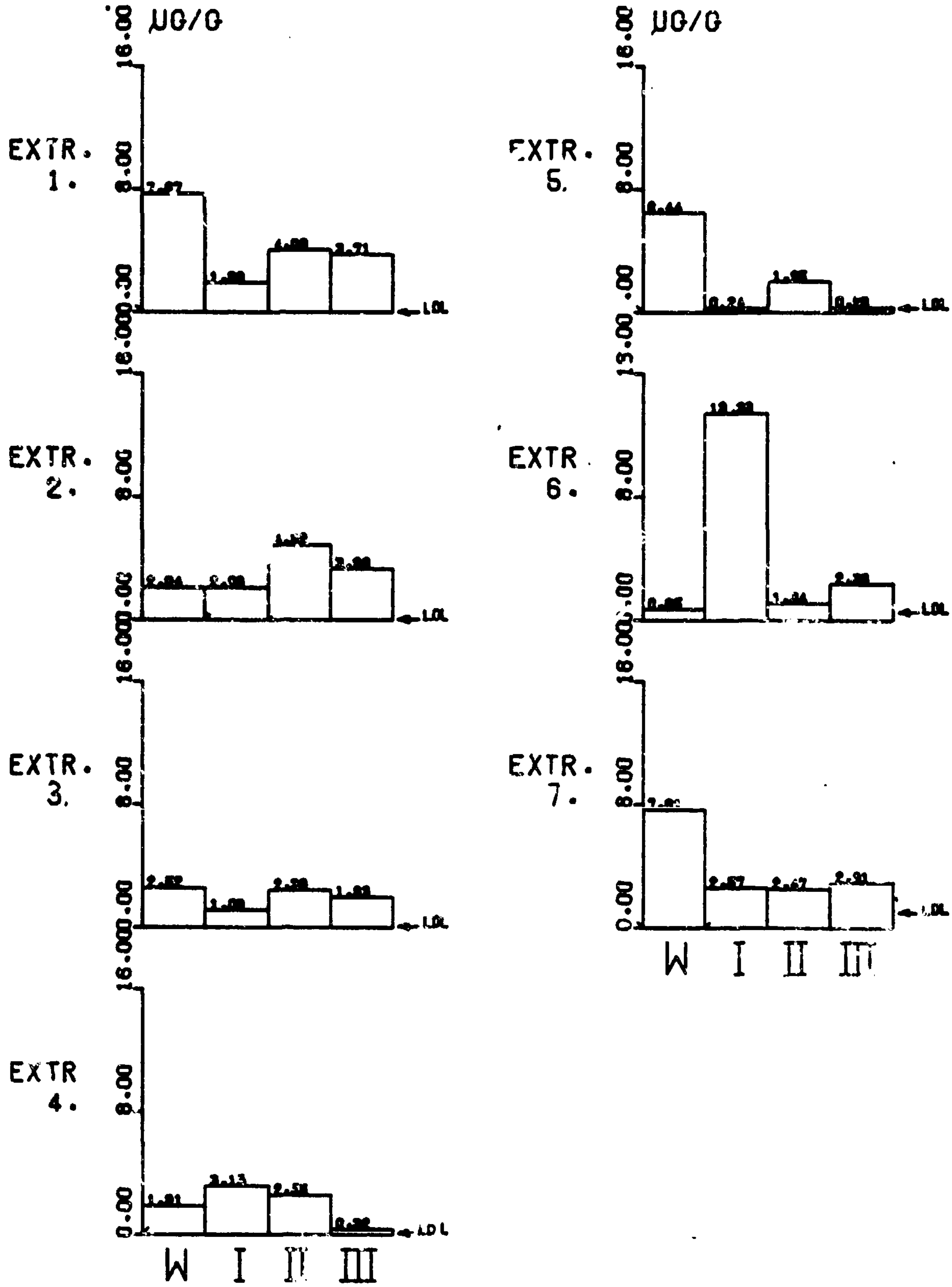


FIGURE 28. WEIGHT OF CADMIUM FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

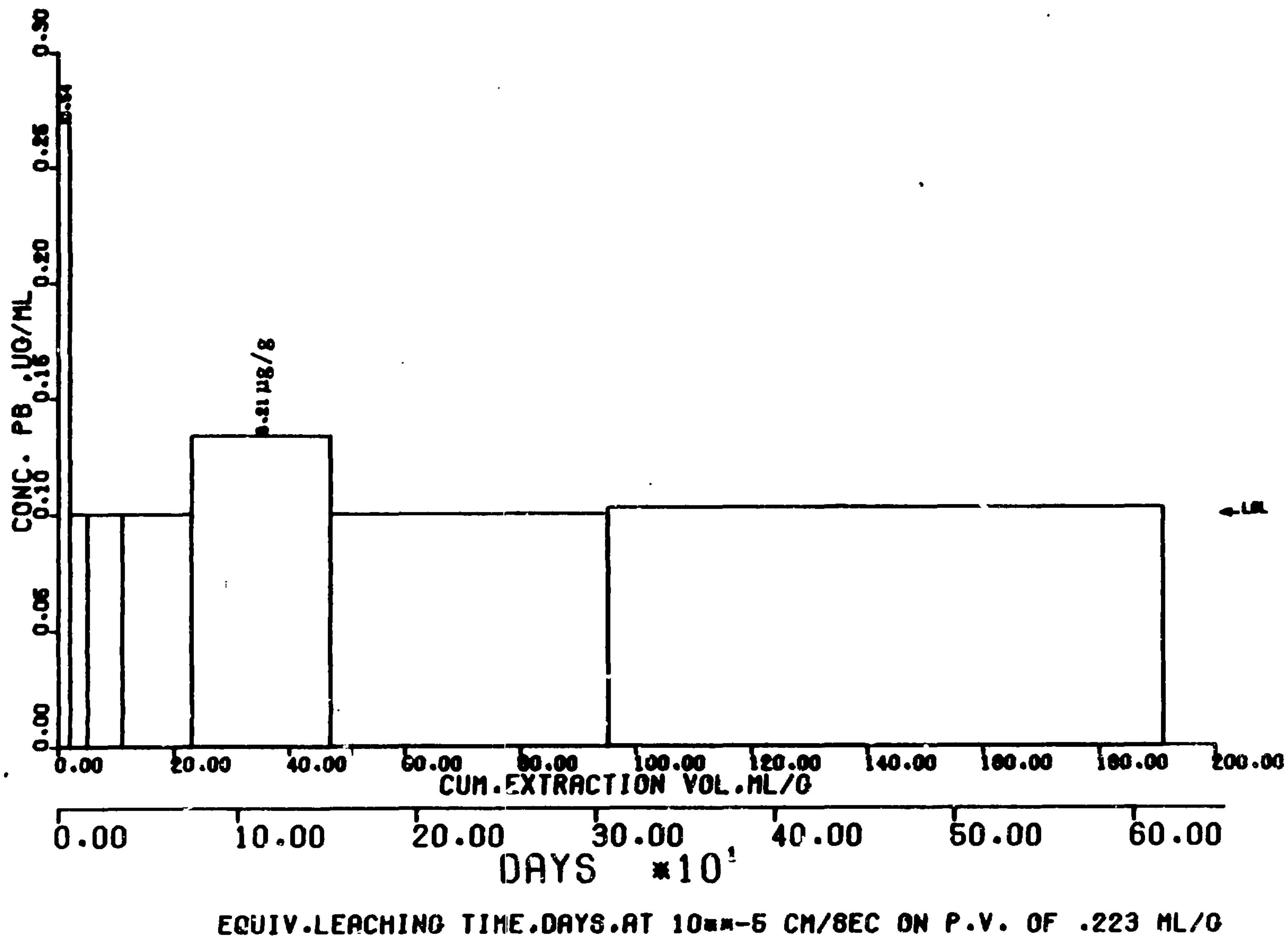


FIGURE 29. EXTRACTION OF LEAD FROM ZINC-CARBON BATTERY WASTE.

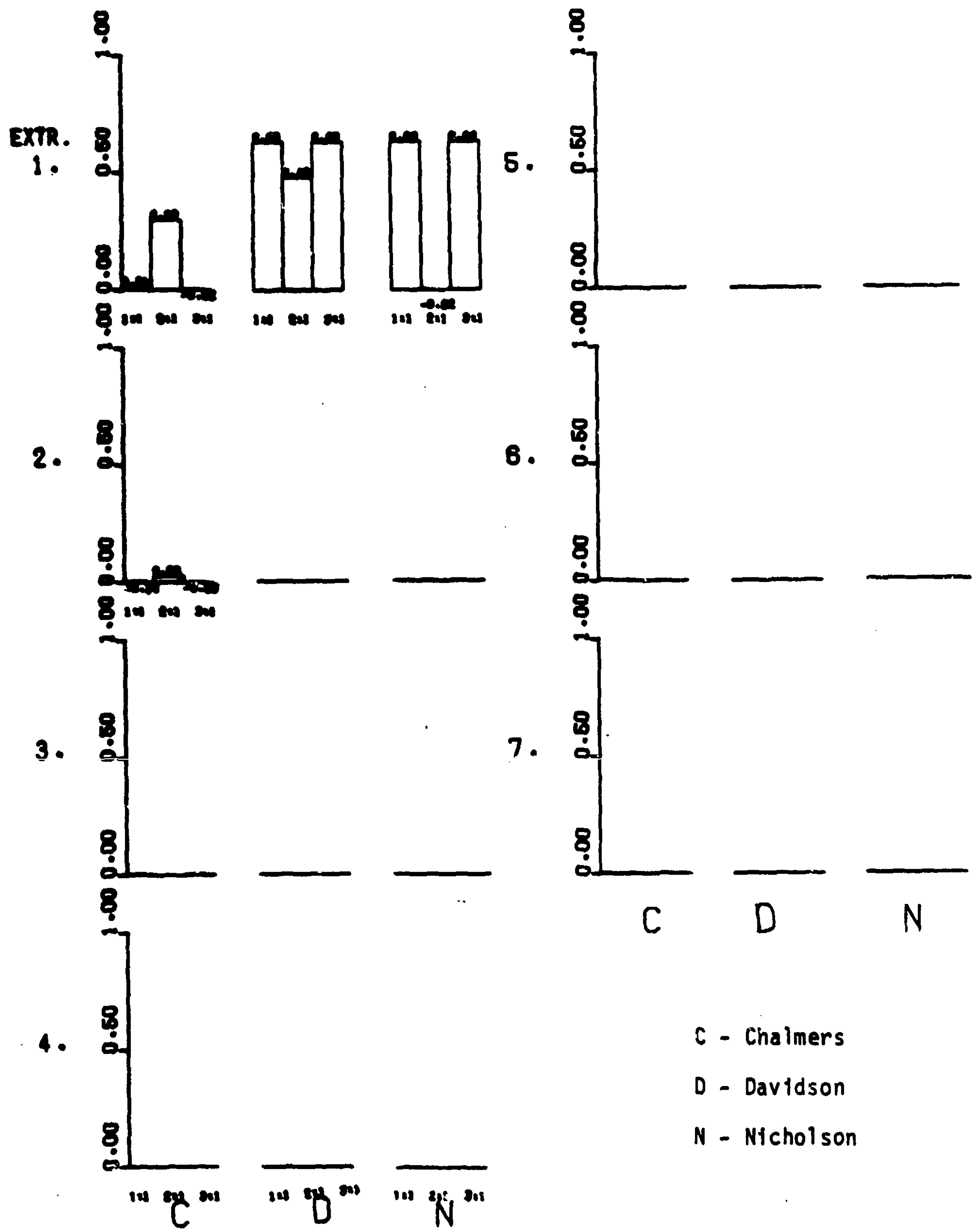


FIGURE 30. COMPARING FRACTION LEAD RETAINED BY SOILS FROM ZINC-CARBON WASTE LEACHATE

TABLE 19. LEAD FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.27	.54										
	I	.27	.53	.01	.54	.01	.01	.01	.99	184.49	89.69	.01	.50
	II	.19	.38	.15	.53	.15	.29	.29	.71	260.89	89.78	.41	22.18
	III	.41	.82	-.44	.38	-.44	-1.16	-1.16	2.16	119.60	89.52	-.54	-28.24
	I+II			.08	.27	.08	.30	.30	.70	1039.[illegible]	89.94	.42	22.87
	I+II+III			-.09	.18	-.09	-.52	-.52	1.52	1081.64	89.95	-.34	-18.87
2	W	<.10	<.30										
	I	.13	.39	-.09	.84	-.09	-.31	-.10	1.31	250.79	89.77	-.22	-12.43
	II	.15	.44	-.05	.93	.11	-.12	.12	1.12	225.00	89.75	.25	13.96
	III	<.10	<.30	.14	.82	-.30	.32	-.37	.68	327.33	89.82	-1.01	-45.10
	I+II			-.07	.42	.01	-.46	.03	1.46	899.38	89.94	.05	2.93
	I+II+III			.00	.28	-.09	.00	-.33	1.00	2954.07	89.98	-.93	-42.97
3	W	<.10	<.60										
	I	<.10	<.60										
	II	.12	.71										
	III	<.10	<.60										
	I+II												
	I+II+III												
4	W	<.10	<1.20										
	I	<.10	<1.20										
	II	<.10	<1.20										
	III	<.10	<1.20										
	I+II												
	I+II+III												
5	W	.13	3.21										
	I	<.10	<2.40										
	II	.11	2.64										
	III	<.10	<2.40										
	I+II												
	I+II+III												
6	W	<.10	<4.80										
	I	.11	5.49										
	II	<.10	<4.80										
	III	<.10	<4.80										
	I+II												
	I+II+III												
7	W	.10	9.05										
	I	<.10	<9.60										
	II	<.10	<9.60										
	III	.12	11.81										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

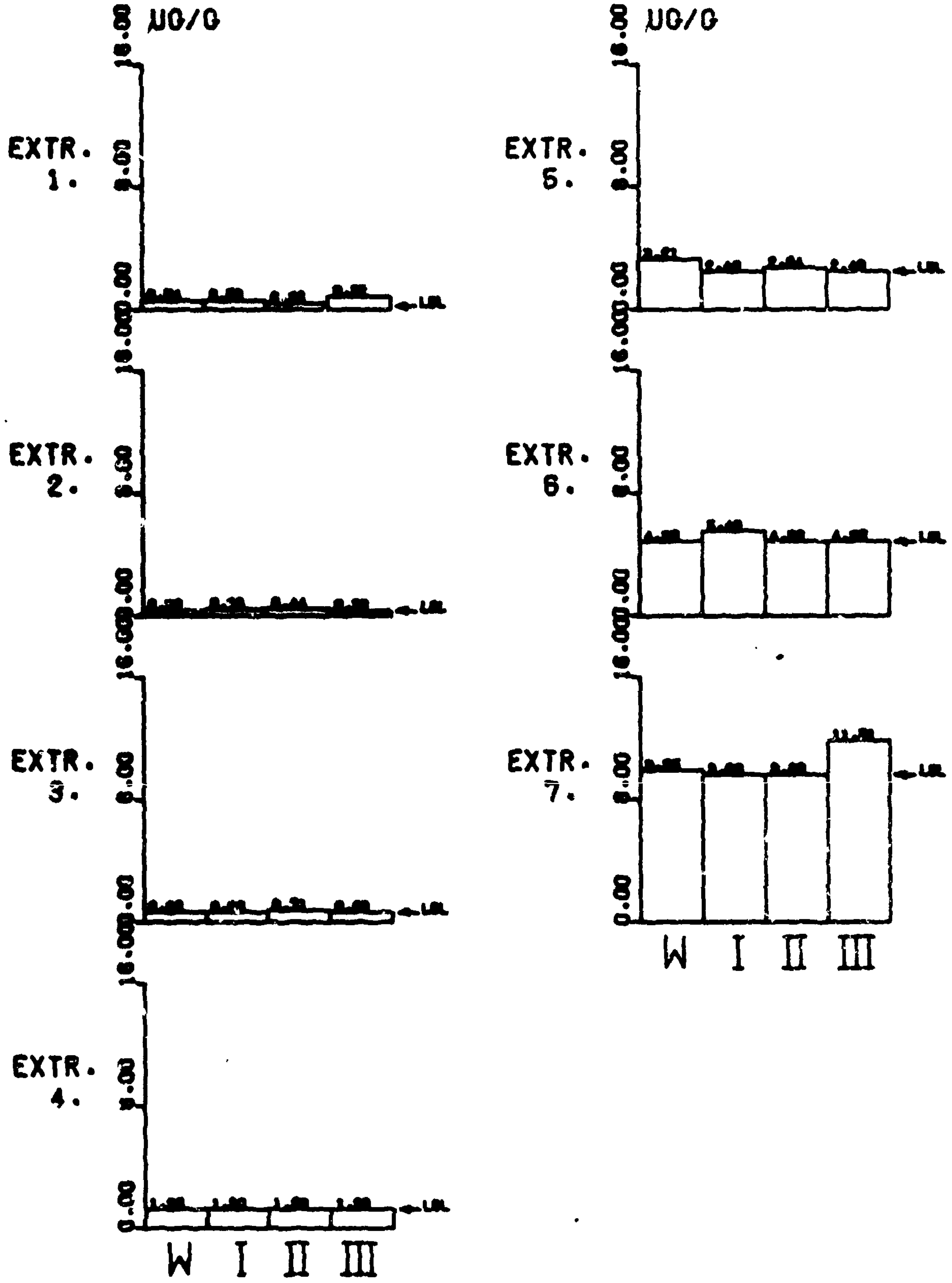


FIGURE 31. WEIGHT OF LEAD FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

TABLE 20. LEAD FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.27	.54										
	I	<.10	<.20	.34	.54	.34	.63	.63	.37	771.70	89.93	1.70	59.40
	II	.14	.28	-.08	.20	-.08	-.41	-.41	1.41	545.91	89.90	-.29	-16.21
	III	<.10	<.20	.08	.28	.08	.29	.29	.71	778.41	89.93	.41	22.20
	I+II			.13	.27	.13	.48	.48	.52	2105.71	89.97	.91	42.39
	I+II+III			.11	.18	.11	.63	.63	.37	6931.70	89.99	1.70	59.40
2	W	<.10	<.30										
	I	<.10	<.30										
	II	<.10	<.30										
	III	<.10	<.30										
	I+II												
	I+II+III												
3	W	<.10	<.60										
	I	<.10	<.60										
	II	<.10	<.60										
	III	.11	.60										
	I+II												
	I+II+III												
4	W	<.10	<1.20										
	I	<.10	<1.20										
	II	.11	1.31										
	III	<.10	<1.20										
	I+II												
	I+II+III												
5	W	.13	3.21										
	I	<.10	<2.40										
	II	.12	2.88										
	III	<.10	<2.40										
	I+II												
	I+II+III												
6	W	<.10	<4.00										
	I	<.10	<4.00										
	II	<.10	<4.00										
	III	<.10	<4.00										
	I+II												
	I+II+III												
7	W	.10	9.85										
	I	<.10	<9.60										
	II	<.10	<9.60										
	III	.13	12.66										
	I+II												
	I+II+III												

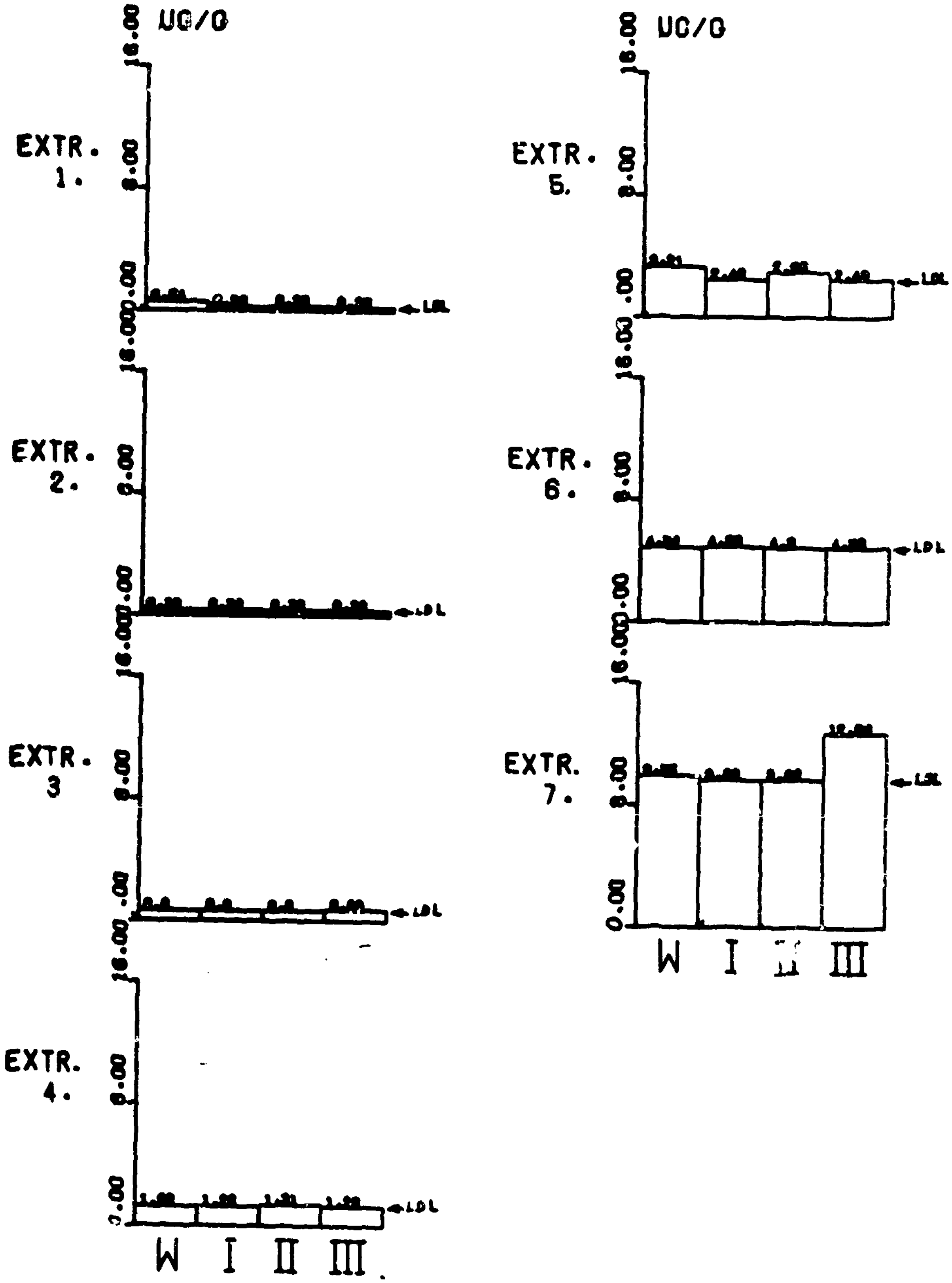


FIGURE 32. WEIGHT OF LEAD FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

TABLE 21. LEAD FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	0	.27	.54										
	I	.10	.20	.34	.54	.34	.63	.63	.37	499.70	89.89	1.70	59.48
	II	.33	.66	-.46	.20	-.45	-2.28	-2.28	3.28	151.28	89.62	-.69	-34.79
	III	<.10	<.20	.46	.66	.46	.69	.69	.31	500.28	89.89	2.28	66.29
	I+II			-.06	.27	-.06	-.22	-.22	1.22	507.71	89.91	-.18	-10.04
	I+II+III			.11	.18	.11	.63	.63	.37	4403.70	89.99	1.70	59.48
2	0	<.10	<.30										
	I	<.10	<.30										
	II	.12	.37										
	III	.12	.37										
	I+II												
	I+II+III												
3	0	<.10	<.60										
	I	<.10	<.60										
	II	.15	.90										
	III	<.10	<.60										
	I+II												
	I+II+III												
4	0	<.10	<1.20										
	I	<.10	<1.20										
	II	<.10	<1.20										
	III	.12	1.44										
	I+II												
	I+II+III												
5	0	.13	3.21										
	I	<.10	<2.40										
	II	<.10	<2.40										
	III	<.10	<2.40										
	I+II												
	I+II+III												
6	0	<.10	<4.80										
	I	.20	9.62										
	II	<.10	<4.80										
	III	<.10	<4.80										
	I+II												
	I+II+III												
7	0	.10	9.85										
	I	<.10	<9.60										
	II	<.10	<9.60										
	III	<.10	<9.60										
	I+II												
	I+II+III												

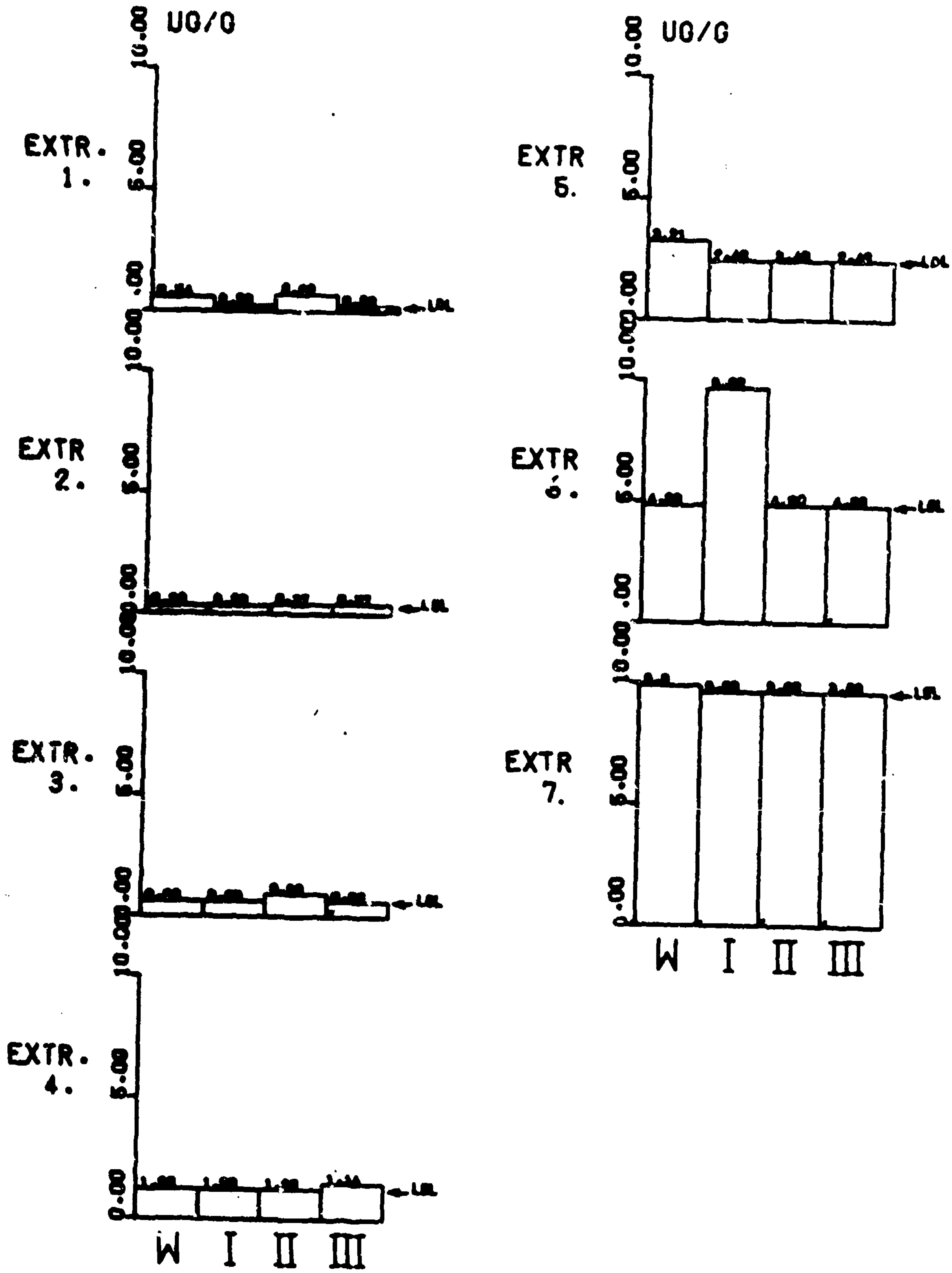


FIGURE 33. WEIGHT OF LEAD FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

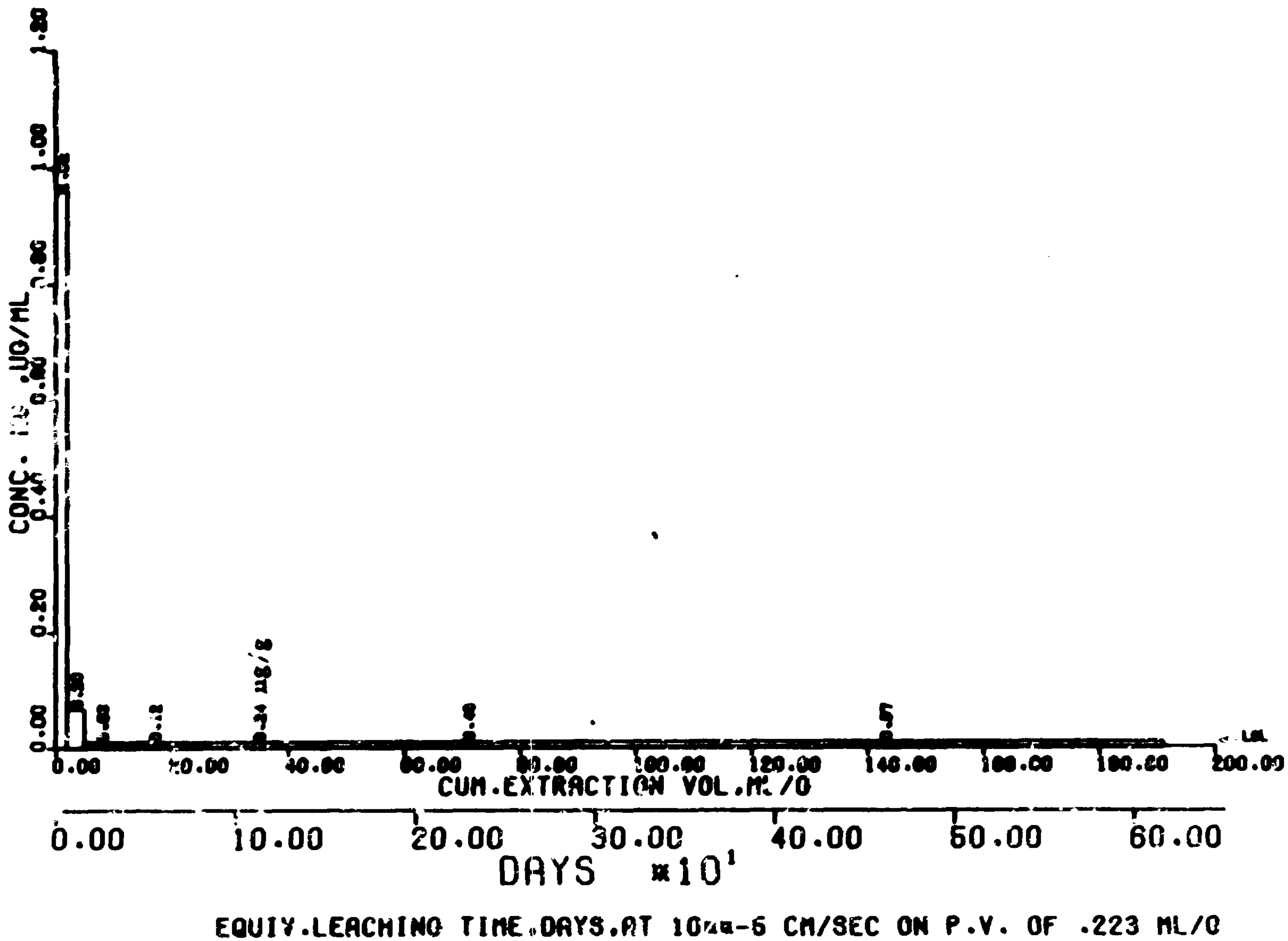


FIGURE 34. EXTRACTION OF MERCURY FROM ZINC-CARBON BATTERY WASTE.

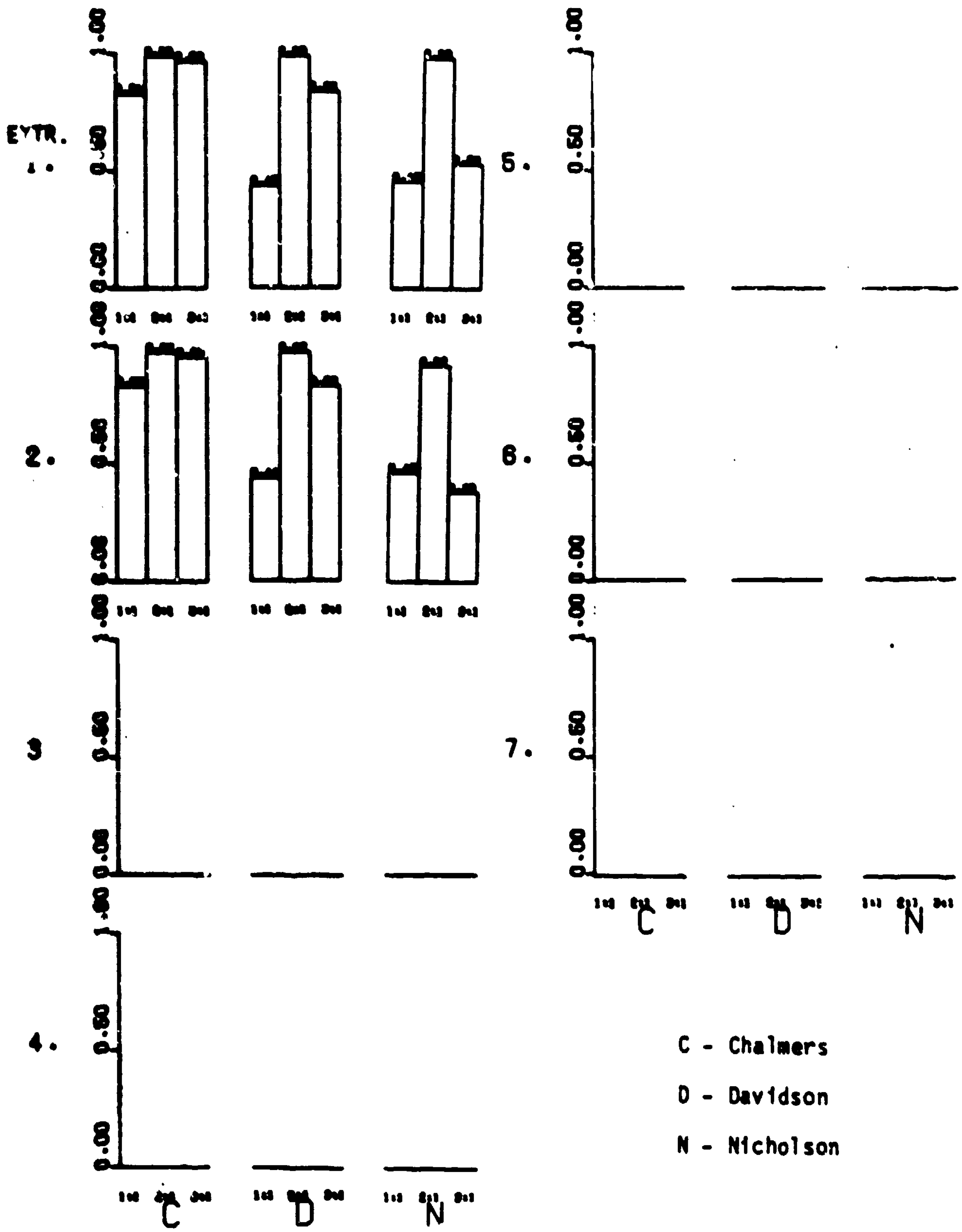


FIGURE 35. COMPARING FRACTION MERCURY RETAINED BY SOILS FROM ZINC-CARBON BATTERY WASTE LEACHATE.

TABLE 22. MERCURY FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	0	.96	1.92										
	I	.17	.33	1.57	1.72	1.59	.83	.83	.17	4.76	78.13	4.76	78.13
	II	<.01	<.02	.31	.33	.34	.93	.93	.07	12.75	85.52	12.75	85.52
	III	.94	87	-.05	.02	-.05	-1.92	-1.92	2.92	-.66	-33.31	-.66	-33.31
	I+II			.95	.96	.95	.99	.99	.01	78.17	89.27	78.17	89.27
	I+II+III			.60	.64	.62	.96	.96	.04	26.14	87.81	26.14	87.81
2	0	.07	.20										
	I	<.01	<.03	.17	2.12	1.76	.05	.83	.15	57.93	89.01	57.93	89.01
	II	<.01	<.03	.00	.36	.31	.00	.85	1.00	10.20	84.40	10.20	84.40
	III	<.01	<.03	.00	.05	-.05	.00	-.85	1.00	-1.53	-56.89	-1.53	-56.89
	I+II			.00	1.66	1.03	.05	.97	.15	68.13	89.16	68.13	89.16
	I+II+III			.06	.71	.67	.05	.95	.15	66.64	89.14	66.64	89.14
3	0	<.01	<.06										
	I	<.01	<.06	.00	2.10	1.76	.00	.81	1.00	28.97	88.02	28.97	88.02
	II	<.01	<.06	.00	.42	.31	.00	.73	1.00	5.10	78.91	5.10	78.91
	III	<.01	<.06	.06	.12	-.05	.00	-.40	1.00	-.77	-37.40	-.77	-37.40
	I+II			.00	1.09	1.03	.00	.95	1.00	34.07	88.32	34.07	88.32
	I+II+III			.00	.73	.67	.00	.93	1.00	33.30	88.28	33.30	88.28
4	0	.04	.12										
	I	.00	.91	-.79	2.30	.97	-6.50	.42	7.50	1.06	46.79	1.06	46.79
	II	<.04	<.12										
	III	<.04	<.12										
	I+II												
	I+II+III												
5	0	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	0	<.01	<.40										
	I	<.01	<.40										
	II	<.01	<.40										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	0	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

The remainder of the table was not calculated because the concentrations were below the detection limit.

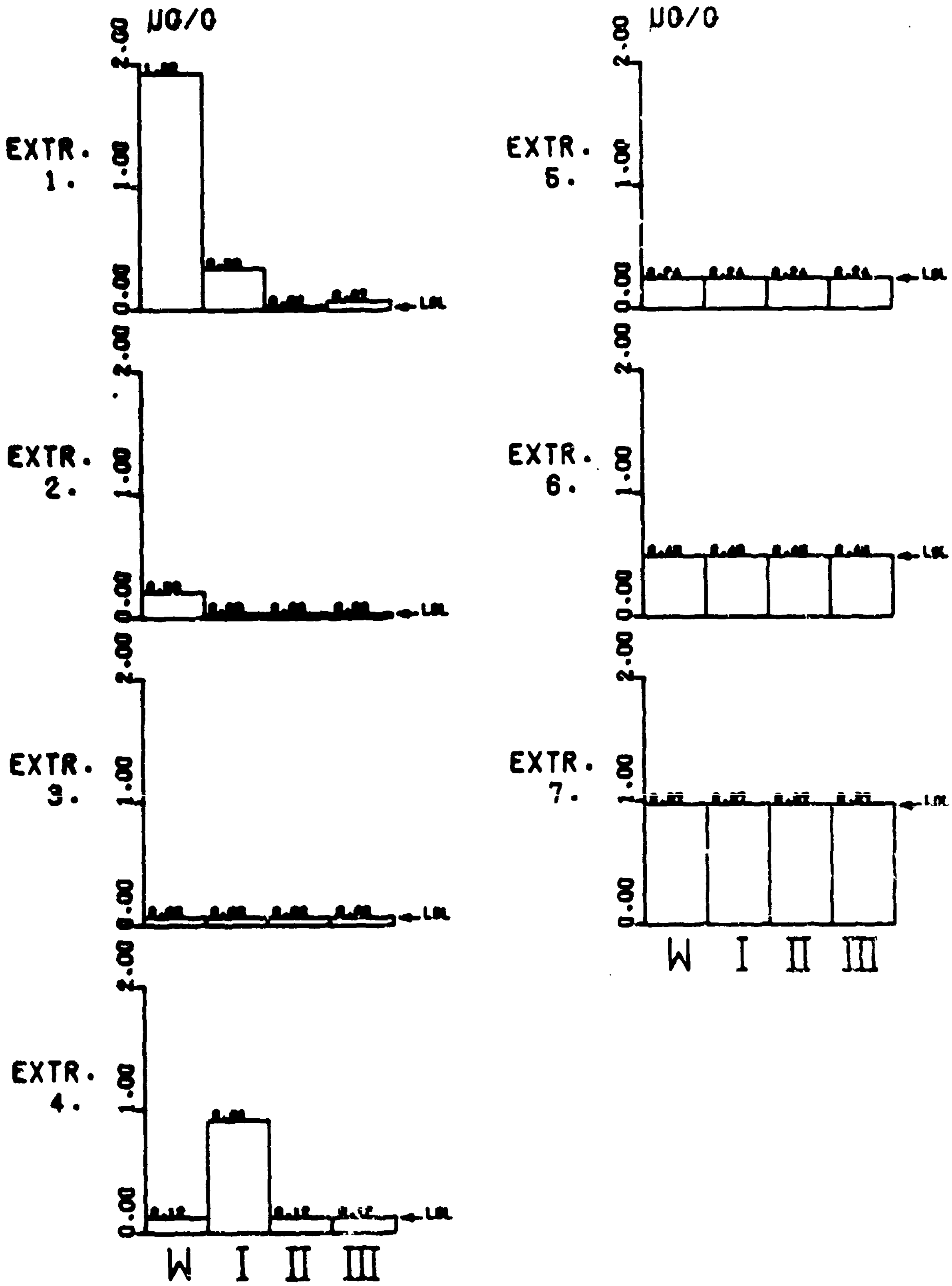


FIGURE 36. WEIGHT OF MERCURY FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

TABLE 23. MERCURY FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.96	1.92										
	I	.55	1.09	.83	1.92	.83	.43	.43	.57	.76	37.21	.76	37.21
	II	.02	.03	1.06	1.09	1.06	.97	.97	.03	35.00	88.36	35.00	88.36
	III	.16	.32	-.29	.03	-.29	-9.67	-9.67	10.67	-.91	-42.18	-.91	-42.18
	I+II			.94	.96	.94	.98	.98	.02	62.33	89.08	62.33	89.08
	I+II+III			.53	.64	.53	.83	.83	.17	4.94	78.55	4.94	78.55
2	W	.07	.20										
	I	.04	.11	.09	2.12	.92	.47	.44	.53	8.70	83.44	8.70	83.44
	II	<.01	<.03	.08	1.20	1.14	.71	.95	.29	37.50	88.47	37.50	88.47
	III	.02	.05	-.02	.06	-.31	-.50	-5.00	1.50	-6.70	-81.61	-6.70	-81.61
	I+II			.00	1.06	1.03	.05	.97	.15	67.93	89.16	67.93	89.16
	I+II+III			.05	.71	.58	.77	.83	.23	38.51	88.51	38.51	88.51
3	W	<.01	<.06										
	I	<.01	<.06										
	II	<.01	<.06										
	III	<.01	<.06										
	I+II												
	I+II+III												
4	W	<.01	<.12										
	I	<.01	<.12										
	II	<.01	<.12										
	III	<.01	<.12										
	I+II												
	I+II+III												
5	W	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	.07	3.15										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

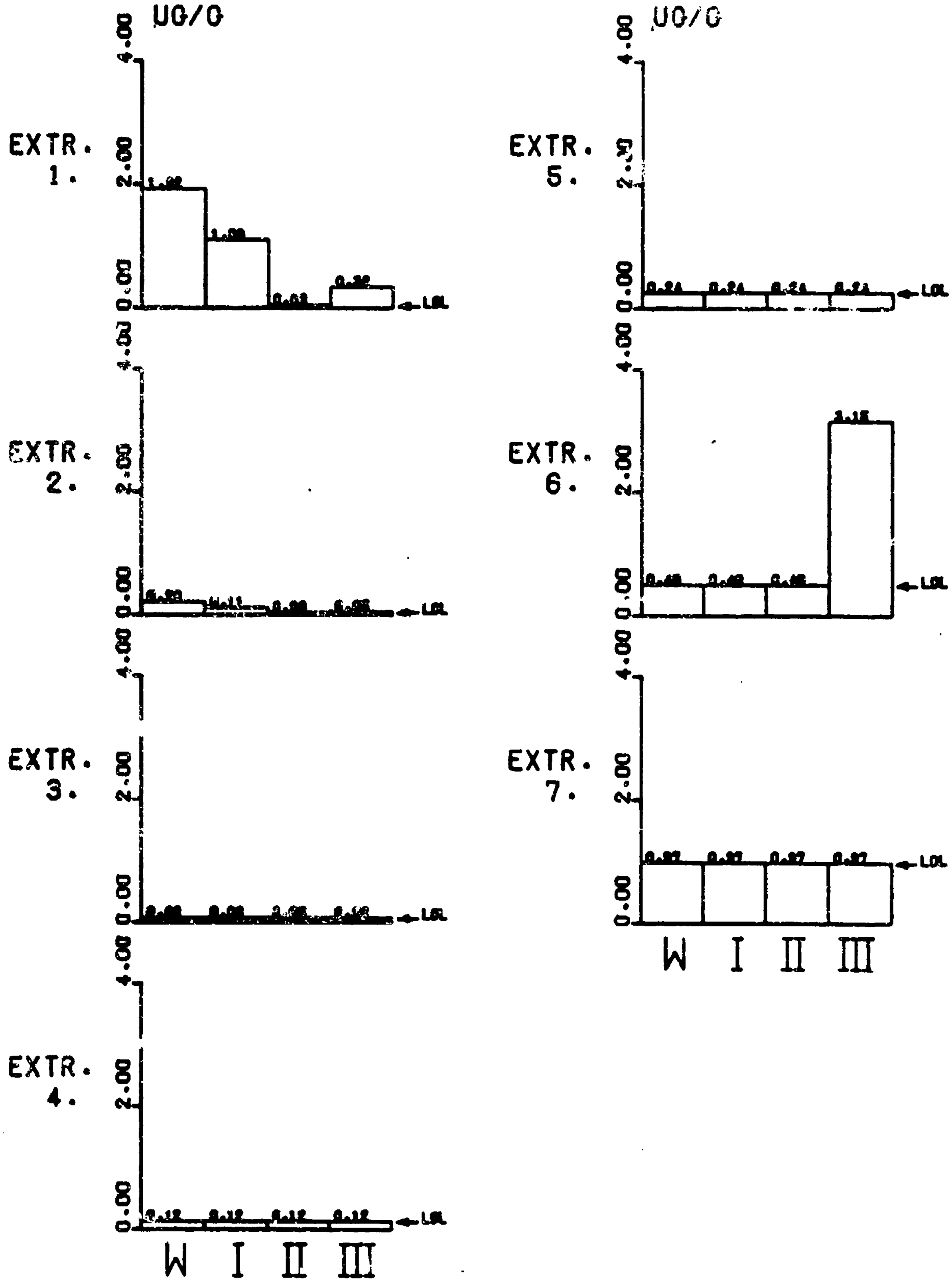


FIGURE 37. WEIGHT OF MERCURY FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

TABLE 24. MERCURY FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.96	1.92										
	I	.53	1.05	.87	1.92	.87	.45	.45	.55	.83	39.59	.83	39.59
	II	.02	.04	1.01	1.05	1.01	.96	.96	.04	25.00	87.71	25.00	87.71
	III	.45	.91	-.87	.04	-.87	-21.50	-21.50	22.50	-.96	-43.70	-.96	-43.70
	I+II			.94	.96	.94	.98	.98	.02	46.50	88.77	46.50	88.77
	I+II+III			.34	.64	.34	.53	.53	.47	1.11	48.01	1.11	48.01
2	W	.07	.20										
	I	.03	.09	.11	2.12	.98	.55	.46	.45	10.76	84.69	10.76	84.69
	II	.05	.14	-.05	1.14	.96	-.50	.85	1.50	7.07	81.95	7.07	81.95
	III	.14	.41	-.27	.18	-1.14	-2.00	-6.46	3.00	-2.79	-70.28	-2.79	-70.28
	I+II			.03	1.06	.97	.32	.92	.68	14.24	85.98	14.24	85.98
	I+II+III			-.07	.71	.27	-1.05	.38	2.05	1.96	62.95	1.96	62.95
3	W	<.01	<.06										
	I	<.01	<.06										
	II	<.01	<.06										
	III	<.01	.07										
	I+II												
	I+II+III												
4	W	<.01	<.12										
	I	<.01	<.12										
	II	<.01	<.12										
	III	<.01	<.12										
	I+II												
	I+II+III												
5	W	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

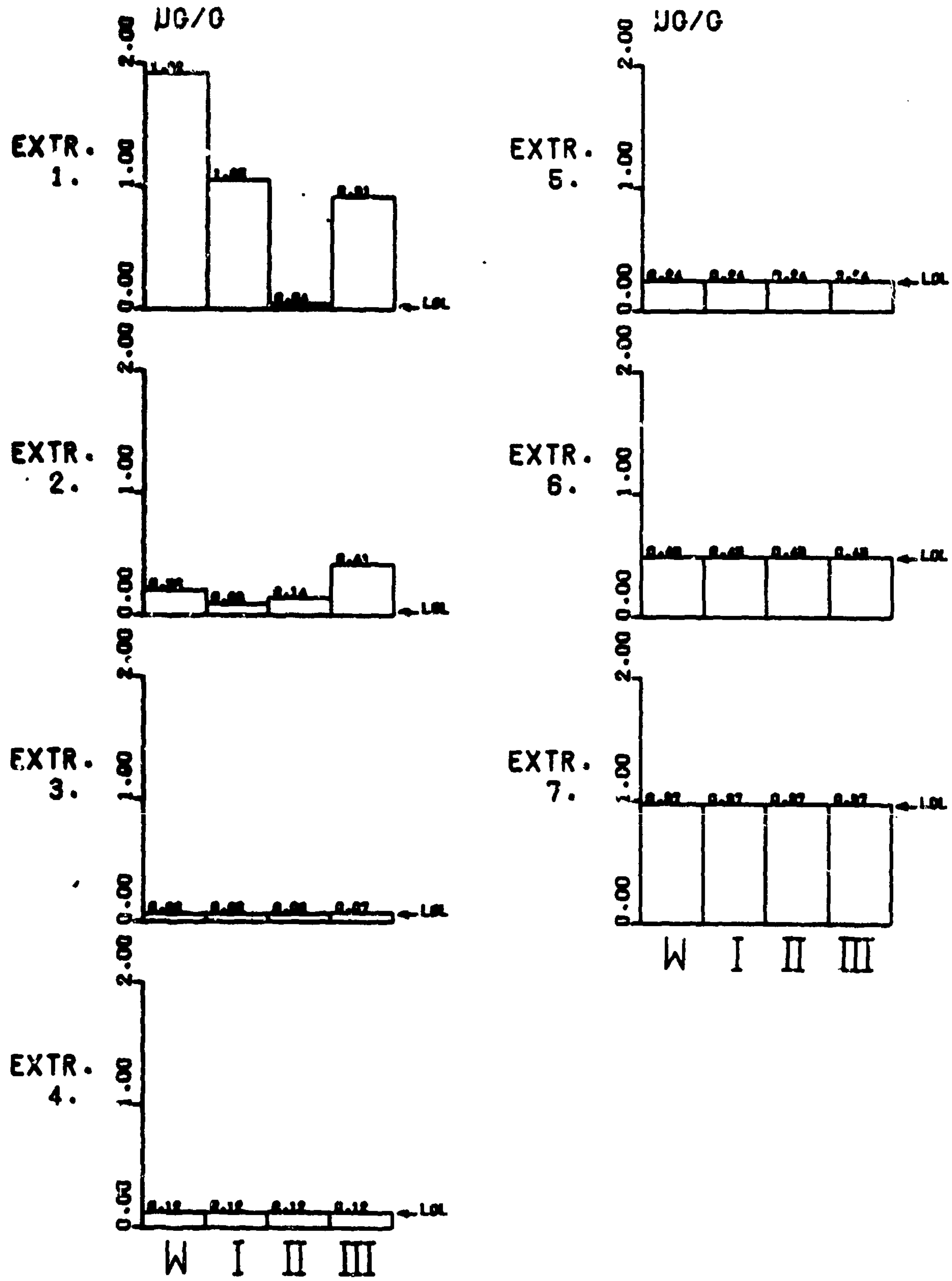


FIGURE 38. WEIGHT OF MERCURY FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

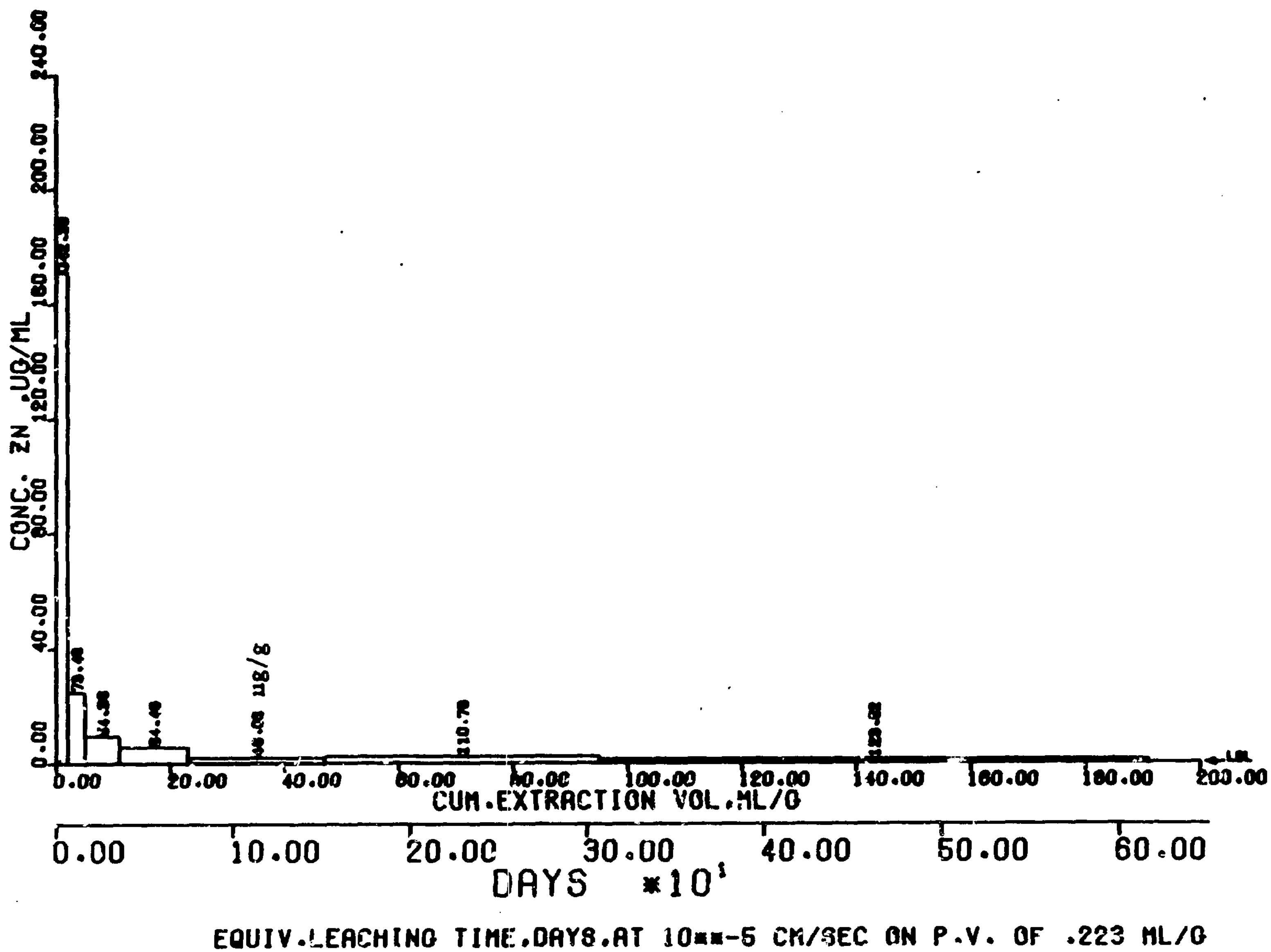


FIGURE 39. EXTRACTION OF ZINC FROM ZINC-CARBON BATTERY WASTE.

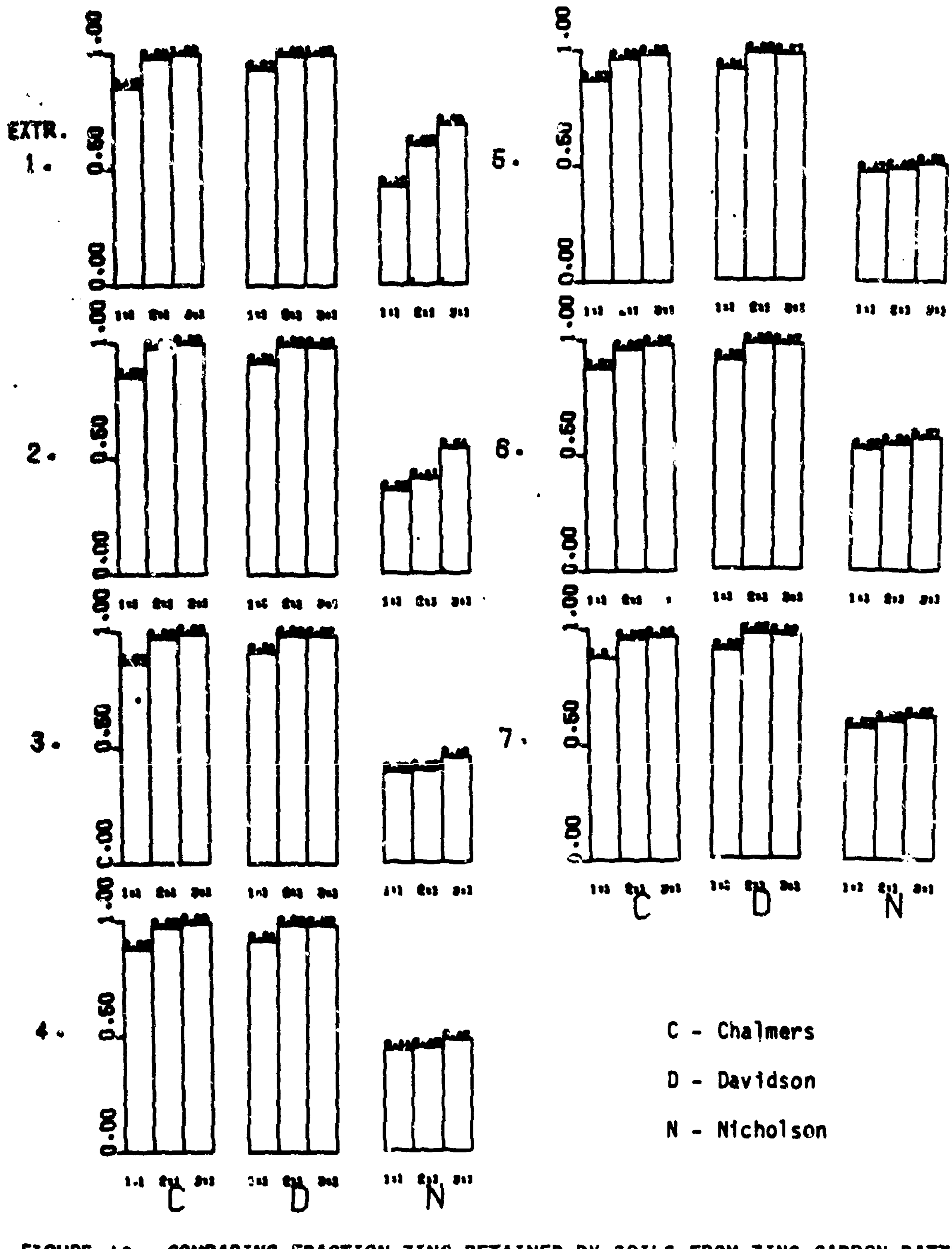


FIGURE 40. COMPARING FRACTION ZINC RETAINED BY SOILS FROM ZINC-CARBON BATTERY WASTE LEACHATE.

TABLE 25. ZINC FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	171.20	342.39										
	I	24.90	49.79	292.60	342.39	292.60	.85	.85	.15	7.12	82.00	5.88	80.34
	II	3.26	6.51	43.28	49.79	43.28	.87	.87	.13	16.13	86.45	6.64	81.44
	III	.70	1.40	5.11	6.51	5.11	.78	.78	.22	47.66	88.80	3.64	74.64
	I+II			167.94	171.20	167.94	.98	.98	.02	89.50	89.36	51.56	88.89
	I+II+III			113.66	114.13	113.66	1.00	1.00	.00	639.07	89.91	242.00	89.76
2	W	24.49	73.40										
	I	3.94	11.80	61.60	415.07	354.20	.84	.85	.16	35.02	88.36	29.82	88.08
	II	1.31	3.92	7.95	61.67	51.23	.67	.83	.33	28.81	88.01	13.06	85.62
	III	.40	1.45	2.47	10.44	7.50	.63	.73	.37	47.70	88.80	5.21	79.14
	I+II			34.70	287.93	282.71	.95	.97	.05	166.32	89.66	103.32	89.45
	I+II+III			24.01	138.62	137.67	.98	.99	.02	666.40	89.91	283.97	89.80
3	W	9.06	54.36										
	I	.52	3.12	51.24	470.23	405.43	.94	.86	.06	149.71	89.62	129.91	89.56
	II	.62	3.73	-.61	64.79	50.63	-.19	.78	1.19	30.17	88.10	13.58	85.79
	III	.47	2.82	.91	14.17	8.49	.24	.60	.76	24.94	87.70	3.01	71.64
	I+II			25.32	235.11	228.03	.93	.97	.07	188.70	89.70	122.37	89.53
	I+II+III			17.10	156.74	154.05	.95	.99	.05	362.24	89.84	164.06	89.65
4	W	5.37	64.40										
	I	.19	2.30	62.10	534.70	467.61	.96	.87	.04	229.90	89.75	203.06	89.72
	II	.21	2.55	-.24	67.09	50.38	-.11	.75	1.11	44.00	88.70	19.80	87.11
	III	.12	1.45	1.09	16.71	9.50	.43	.57	.57	49.00	88.83	6.59	81.37
	I+II			30.97	267.35	259.00	.96	.97	.04	300.64	89.81	203.52	89.72
	I+II+III			21.01	178.23	175.06	.98	.99	.02	745.17	89.92	362.74	89.84
5	W	1.92	46.06										
	I	.36	8.73	37.33	580.76	504.94	.81	.87	.19	64.95	89.12	57.86	89.01
	II	.20	4.85	3.88	75.82	54.26	.44	.72	.56	23.94	87.61	11.19	84.89
	III	.16	3.80	.97	21.56	10.55	.20	.49	.80	18.65	86.93	2.72	69.81
	I+II			20.60	290.38	279.60	.89	.96	.11	166.34	89.66	115.35	89.50
	I+II+III			14.06	193.59	189.92	.92	.98	.08	290.31	89.80	146.90	89.61
6	W	2.31	110.78										
	I	.25	12.12	98.66	691.54	603.60	.89	.87	.11	54.90	88.96	49.80	88.85
	II	.20	9.70	2.42	87.94	56.69	.20	.64	.80	12.22	85.32	5.85	80.29
	III	.16	7.51	2.18	31.25	12.73	.23	.41	.77	9.92	84.24	1.69	59.45
	I+II			50.54	345.77	330.14	.91	.95	.09	93.59	89.39	68.18	89.16
	I+II+III			34.42	230.51	224.34	.93	.97	.07	163.58	89.65	89.56	89.36
7	W	1.29	123.62										
	I	.18	17.45	106.17	815.16	709.77	.86	.87	.14	44.21	88.70	40.67	88.59
	II	.08	7.27	10.18	105.39	66.87	.58	.63	.42	17.69	86.77	9.21	83.79
	III	.12	11.15	-3.88	30.53	8.85	-.53	.23	1.53	6.34	81.03	.79	38.45
	I+II			58.18	407.58	388.32	.94	.95	.06	140.79	89.59	106.60	89.46
	I+II+III			37.49	271.72	261.83	.91	.96	.09	120.33	89.52	70.44	89.19

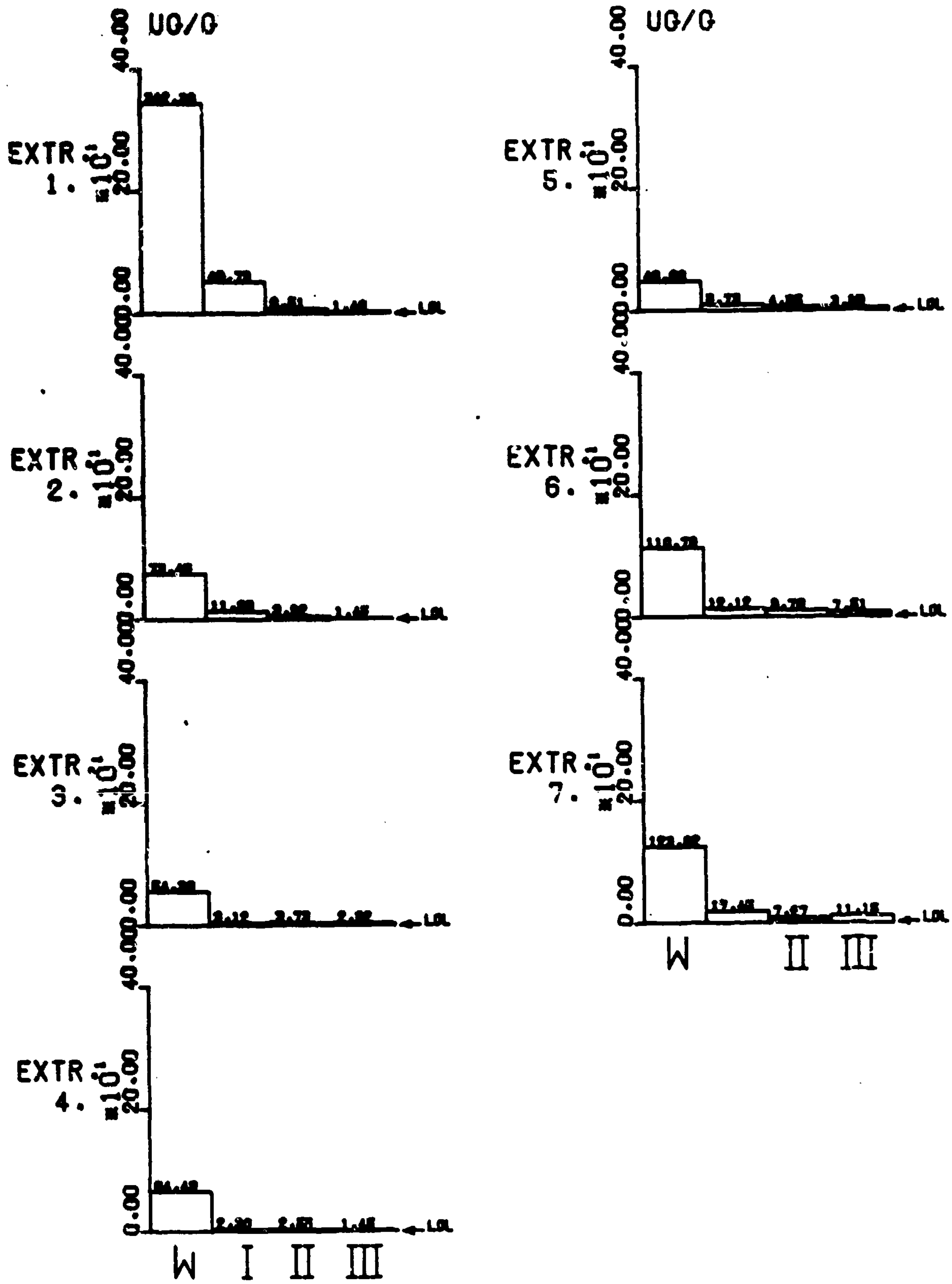


FIGURE 41. WEIGHT OF ZINC FROM ZINC-CARBON BATTERY WASTE ON CHALMERS SOIL.

TABLE 26. ZINC FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. US/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	171.20	342.39										
	I	11.57	23.15	319.24	342.39	319.24	.93	.93	.07	16.17	86.46	13.79	85.85
	II	1.35	2.71	20.44	23.15	20.44	.88	.88	.12	27.07	87.95	7.55	82.46
	III	.64	1.27	1.43	2.71	1.43	.53	.53	.47	44.35	88.71	1.13	48.42
	I+II			169.84	171.20	169.84	.99	.99	.01	206.77	89.72	125.49	89.54
	I+II+III			113.71	114.13	113.71	1.00	1.00	.00	657.02	89.91	268.05	89.79
2	W	24.49	73.40										
	I	4.35	13.06	60.42	415.07	379.66	.82	.91	.18	33.20	88.28	29.07	88.03
	II	.72	2.15	10.91	36.21	31.35	.84	.87	.16	40.14	88.57	14.57	86.07
	III	1.69	5.00	-2.72	4.06	-1.49	-1.36	-.31	2.36	10.54	84.58	-.29	-16.36
	I+II			35.66	207.93	205.50	.97	.99	.03	293.32	89.80	191.05	89.70
	I+II+III			22.80	138.62	136.51	.93	.98	.07	170.22	89.68	86.69	89.29
3	W	9.06	54.36										
	I	1.02	6.09	40.27	470.23	427.93	.89	.91	.11	79.29	89.28	70.26	89.18
	II	.54	3.21	2.88	42.30	34.23	.47	.81	.53	27.78	87.94	10.66	84.64
	III	.43	2.58	.64	8.07	-.05	.20	-.11	.80	21.02	87.28	-.33	-18.33
	I+II			25.57	235.11	231.00	.94	.98	.06	212.39	89.73	143.89	89.60
	I+II+III			17.26	156.74	153.77	.95	.98	.05	371.31	89.85	179.11	89.68
4	W	5.37	64.40										
	I	.44	5.33	59.15	534.70	487.07	.92	.91	.08	101.65	89.44	91.34	89.37
	II	.15	1.82	3.51	47.63	37.74	.66	.79	.34	51.01	88.88	20.76	87.24
	III	.17	2.06	-.24	9.07	-1.10	-.13	-.11	1.13	26.10	87.81	-.53	-28.01
	I+II			31.33	267.35	262.41	.97	.98	.03	409.69	89.86	188.60	89.80
	I+II+III			20.81	178.23	174.57	.97	.98	.03	494.43	89.88	254.18	89.77
5	W	1.92	46.06										
	I	.22	5.33	40.72	580.76	527.80	.88	.91	.12	109.29	89.48	98.97	89.42
	II	.07	1.70	3.64	52.96	41.38	.68	.78	.32	56.80	88.99	24.39	87.65
	III	.21	5.09	-3.39	11.50	-4.49	-2.00	-.39	3.00	9.92	84.25	-.88	-41.41
	I+II			22.18	290.38	284.59	.96	.98	.04	465.10	89.88	335.44	89.83
	I+II+III			13.66	193.59	188.23	.89	.97	.11	208.17	89.72	110.93	89.48
6	W	2.[illegible]	110.78										
	I	[illegible]	16.00	94.70	691.54	622.57	.86	.90	.14	42.35	88.65	38.91	88.53
	II	[illegible]	6.79	9.21	68.96	58.59	.58	.73	.42	15.56	86.32	7.45	82.36
	III	.12	5.58	1.21	18.37	-3.28	.18	-.18	.82	9.28	83.85	-.59	-30.45
	I+II			51.99	345.77	336.58	.94	.97	.06	131.60	89.56	99.18	89.42
	I+II+III			35.07	230.51	223.30	.95	.97	.05	208.94	89.73	120.15	89.52
7	W	1.29	123.62										
	I	.16	15.51	106.11	815.16	730.68	.87	.90	.13	50.64	88.87	47.10	88.78
	II	.06	5.82	9.70	84.40	60.29	.63	.71	.38	19.82	87.11	10.36	84.49
	III	.10	9.21	-3.39	24.19	-6.67	-.58	-.28	1.58	5.25	79.21	-.72	-35.91
	I+II			58.90	407.58	395.49	.95	.97	.05	173.78	89.67	135.96	89.58
	I+II+III			38.14	271.72	261.43	.93	.96	.07	138.89	89.59	85.15	89.33

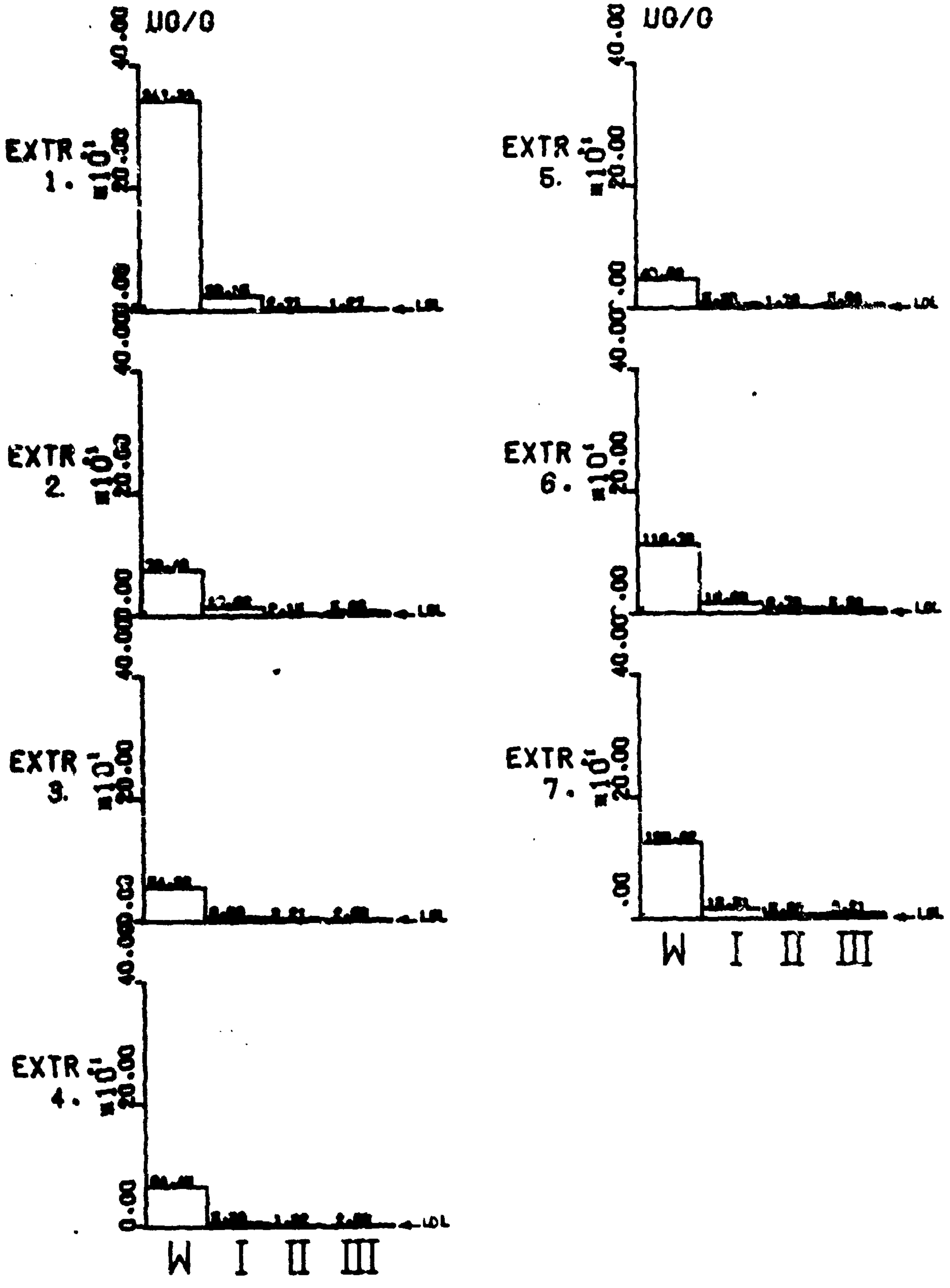


FIGURE 42. WEIGHT OF ZINC FROM ZINC-CARBON BATTERY WASTE ON DAVIDSON SOIL.

TABLE 27. ZINC FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	171.20	342.39										
	I	99.08	198.16	144.23	342.39	144.23	.42	.42	.58	1.11	47.86	.73	36.05
	II	68.38	136.75	61.41	198.16	61.41	.31	.31	.69	1.00	44.89	.45	24.18
	III	53.53	107.06	29.69	136.75	29.69	.22	.22	.78	.98	44.31	.28	15.50
	I+II			132.02	171.20	102.02	.60	.60	.40	3.69	74.84	1.50	56.37
	I+II+III			78.44	114.13	78.44	.69	.69	.31	8.49	83.28	2.29	65.54
2	W	24.49	73.48										
	I	23.43	70.30	3.18	415.87	147.41	.04	.35	.96	3.16	72.45	2.10	64.50
	II	36.58	109.53	-39.24	268.46	22.17	-.56	.08	1.56	.89	41.52	.20	11.44
	III	28.63	85.90	23.63	246.29	53.33	.22	.22	.78	1.49	56.16	.62	31.83
	I+II			-40.03	287.93	84.79	-.49	.41	1.49	4.28	76.85	1.55	57.14
	I+II+III			-4.14	138.62	74.30	-.17	.54	1.17	10.43	84.52	2.59	68.93
3	W	9.06	54.36										
	I	3.35	20.12	34.24	470.23	181.65	.63	.39	.37	12.75	85.51	9.63	83.68
	II	6.38	38.28	-18.18	288.58	3.99	-.90	.01	1.90	2.06	64.08	.10	5.95
	III	10.96	65.75	-27.46	284.59	25.80	-.72	.09	1.72	1.53	56.85	.39	21.40
	I+II			8.03	235.11	92.82	.30	.39	.70	12.66	85.48	4.85	78.34
	I+II+III			-3.00	156.74	70.50	-.21	.45	1.21	13.46	85.75	3.22	72.73
4	W	5.37	64.48										
	I	1.06	12.73	51.75	534.70	233.40	.80	.44	.20	24.22	87.64	10.34	84.00
	II	.96	11.57	1.15	301.30	5.14	.09	.02	.91	6.91	81.76	.44	23.95
	III	1.45	17.02	-8.24	296.16	17.63	-.71	.06	1.71	4.66	77.98	.87	41.67
	I+II			26.45	267.35	119.27	.82	.45	.18	46.46	88.77	20.61	87.22
	I+II+III			14.09	178.23	85.39	.69	.48	.31	46.90	88.78	12.93	85.58
5	W	1.92	46.06										
	I	.31	7.51	38.54	580.76	271.94	.84	.47	.16	46.14	88.76	36.19	88.42
	II	.19	4.48	3.03	308.82	8.17	.40	.03	.60	18.50	86.91	1.22	61.24
	III	.40	9.70	-5.21	388.65	12.42	-1.16	.04	2.16	9.00	83.66	1.28	52.03
	I+II			23.79	298.38	140.06	.90	.48	.10	129.18	89.56	62.46	89.08
	I+II+III			12.12	193.59	97.51	.79	.50	.21	99.63	89.42	30.17	88.10
6	W	2.31	110.78										
	I	.46	22.06	88.72	691.54	360.66	.80	.52	.20	19.74	87.10	16.35	86.50
	II	.32	15.27	6.79	330.08	14.96	.31	.05	.69	5.88	80.34	.98	44.41
	III	.19	8.97	6.30	315.92	18.73	.41	.06	.59	10.43	84.52	2.09	64.41
	I+II			47.75	345.77	187.01	.86	.54	.14	44.19	88.70	24.60	87.67
	I+II+III			33.94	230.51	131.45	.92	.57	.08	119.03	89.52	43.97	88.78
7	W	1.29	123.62										
	I	.23	22.30	101.32	815.16	461.98	.82	.57	.18	24.07	87.62	20.72	87.24
	II	.14	13.57	8.73	353.18	23.68	.39	.07	.61	7.26	82.15	1.74	60.18
	III	.17	16.48	-2.91	329.49	15.82	-.21	.05	1.21	5.58	79.69	.96	43.82
	I+II			55.02	467.58	242.83	.89	.60	.11	57.82	89.01	35.78	88.40
	I+II+III			35.71	271.72	167.16	.87	.62	.13	71.27	89.20	30.42	88.12

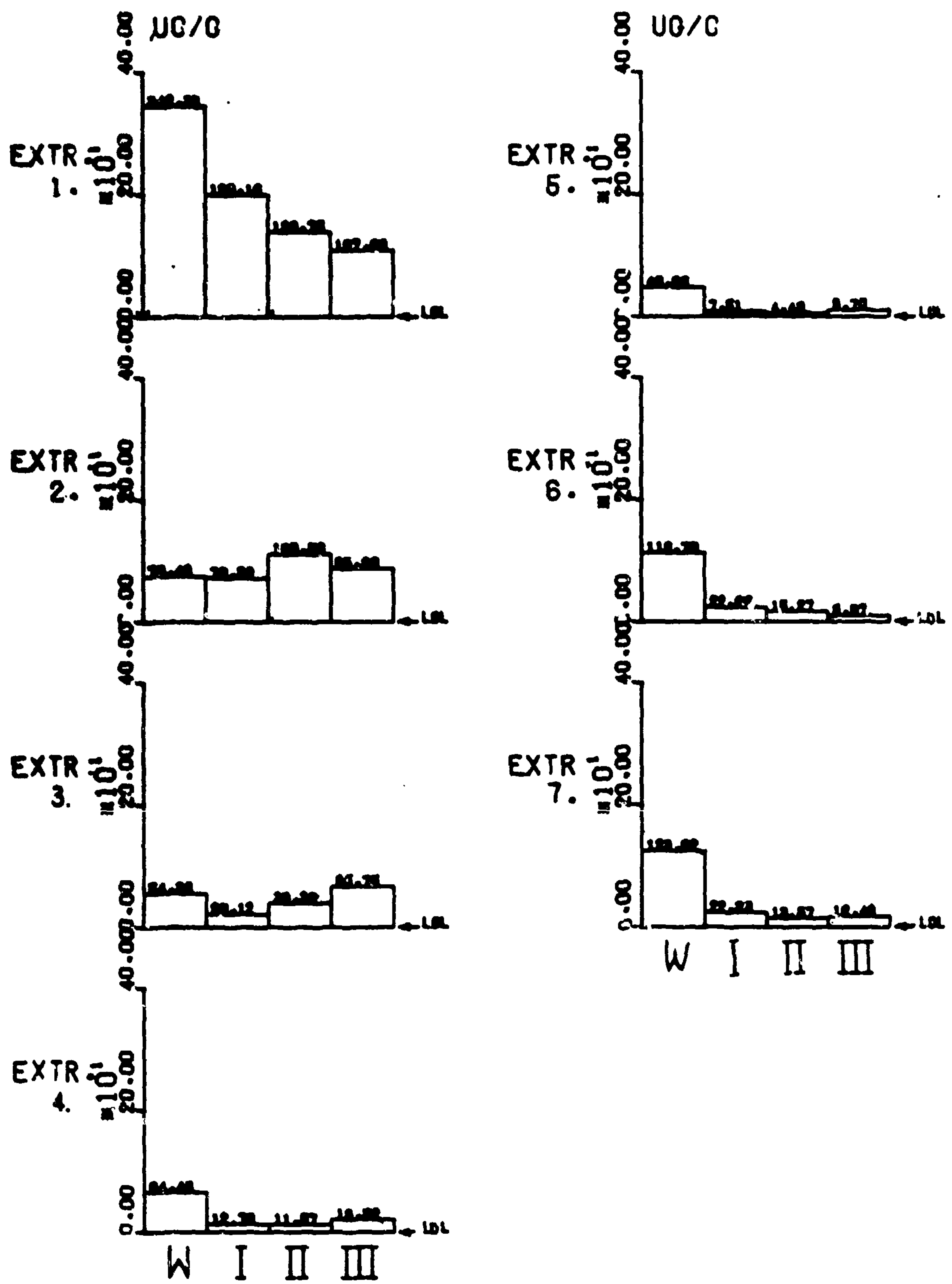


FIGURE 43. WEIGHT OF ZINC FROM ZINC-CARBON BATTERY WASTE ON NICHOLSON SOIL.

TITANIUM DIOXIDE PIGMENT PRODUCTION WASTE

The waste resulting from producing titanium dioxide pigment by the chlorine process was a brown mud. Its leachability by water is summarized in Table 28. The penetration of the individual elements through soil is discussed in the following subsections.

TABLE 28. LEACHABILITY OF TITANIUM DIOXIDE PIGMENT PRODUCTION WASTE

Element	Initial Conc. (μg/ml)	When Concentration Levels Off: Conc. (μg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days	Total Weight Extracted (μg/g waste)	Percentage Extracted
Cr	0.04	0.02	5	47	150	0.91	0.03
Pb	0.48	0.19	3	11	36	3.0	0.01
Ti	0.41	0.14	4	23	75	4.3	0.01

Measurement	Initial	Final	Estim.Tot.Extr. (μ equiv/g)
Conduct. (μ mho)	3,922	74	468.
pH	7.3	7.3	--

As can be seen from Figures 44 to 49, the three soils had similar effects on the pH and conductivity, except that in the first extraction, one to three batches of Chalmers and Davidson soils increased the average hydrogen ion concentration by a factor of 3.6 (calculated from antilog (7.3 - 6.8) = antilog 0.5 = 3.6) while Nicholson soil increased it by a factor of 7.9 (which is pH 7.3 - pH 6.4 = 0.9 orders of magnitude).

Chromium

Figure 50 and Table 28 show that chromium leached out of this waste at very low concentration levels (0.04 μg/ml), giving a total of only 0.91 μg/g waste before the detection limit was reached. This corresponds to a 0.03 percent recovery of the chromium percent in the waste. Tables 29 to 31 and Figures 51 to 54 show that about 40 percent of the chromium was retained by Chalmers soil, 20 percent by Davidson and over 70 percent by Nicholson soil.

Lead

Lead leached out at low levels (0.48 μg/ml initially) and only 3.0 μg lead was solubilized per gram of waste, a recovery of 0.01 percent. (Table 28 and Figure 55.) Tables 32 to 34 and Figures 56 to 59 show that although about 30 percent of the lead was retained from the first extraction, the soil sections started to give up lead. By the third extraction Davidson and Nicholson soils had retained a net of only 16 percent while Chalmers soil had given up an additional amount of its own lead, equivalent to 39 percent of the challenge. (This is shown by the minus sign under the histogram in Figure 56 and in the Fraction Retained Total Challenge column for extraction three of Table 32.

Titanium

Titanium is solubilized from titanium dioxide pigment production waste at very low levels (0.41 μg/ml initially), as shown in Figure 60 and Table 28, such that 0.01 percent (4.3 μg/g) was removed in the seven extractions. The soils were about equally effective in removing titanium from the first extract, but the soils start to give up titanium and by the fourth extraction Nicholson was superior to the other two soils. (Tables 35 to 37 and Figures 61 to 64.)

Summary

The concentrations of chromium, lead, and titanium in the first water-extract of titanium-dioxide pigment production waste were low to very low. The compounds containing these metals apparently were very insoluble, as only a few hundreths of a percent dissolved during the entire series of seven extractions. The concentrations in the later extracts dropped to very low and the soils reduced it even further: Nicholson soil being the most efficient and Chalmers soil the least.

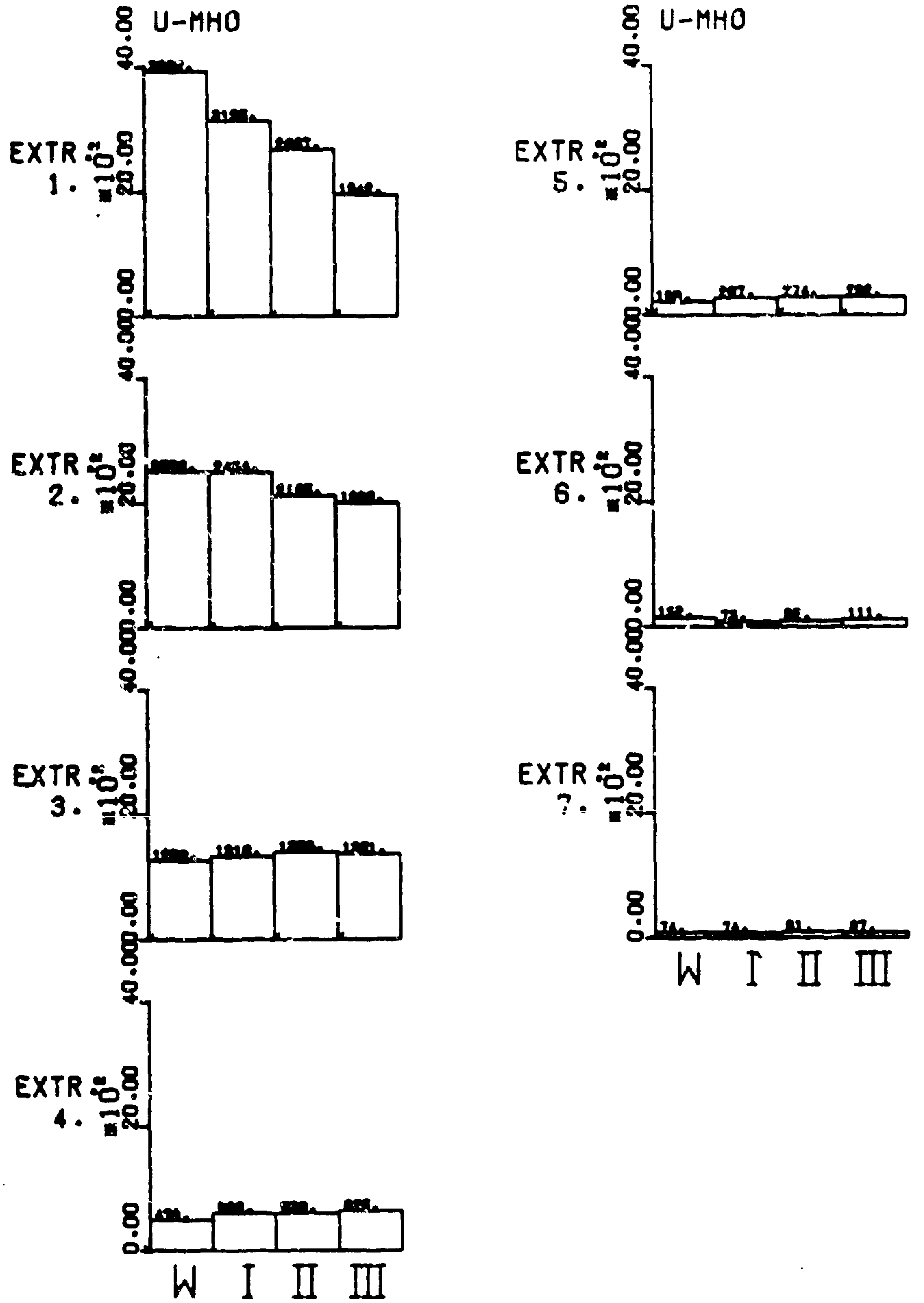


FIGURE 44. CONDUCTANCE OF EXTRACT FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

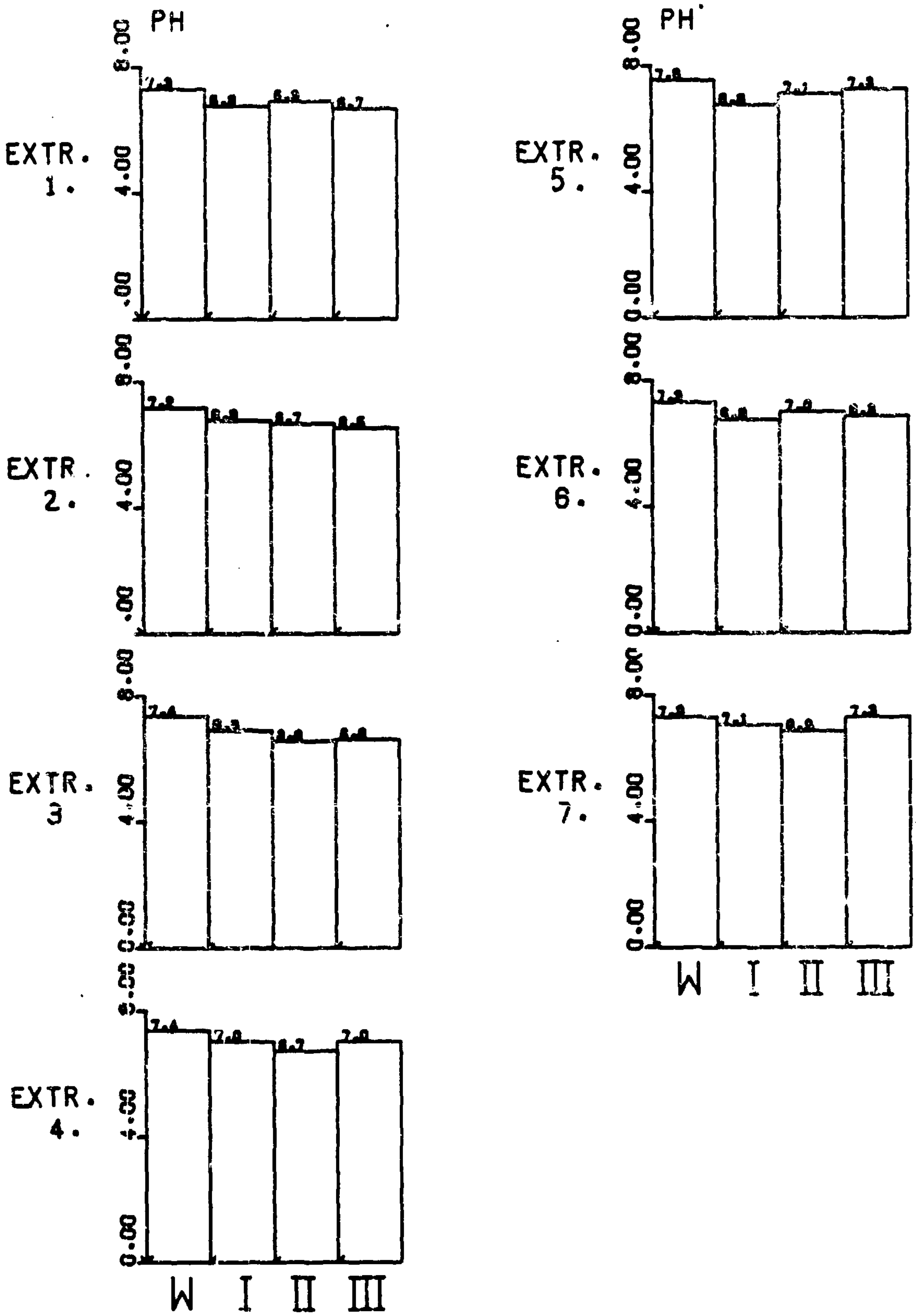


FIGURE 45. pH OF EXTRACT FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

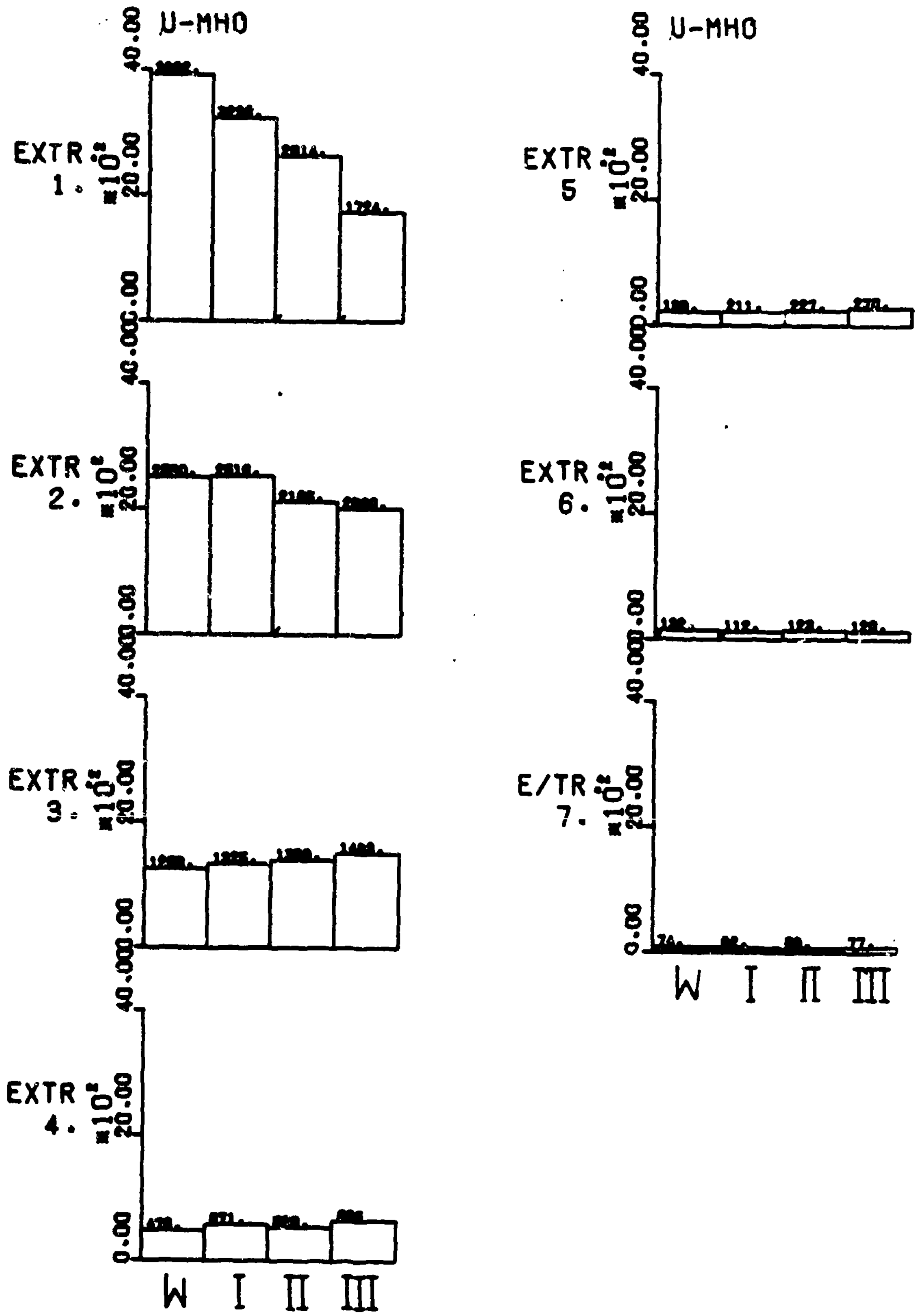


FIGURE 46. CONDUCTANCE OF EXTRACT FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

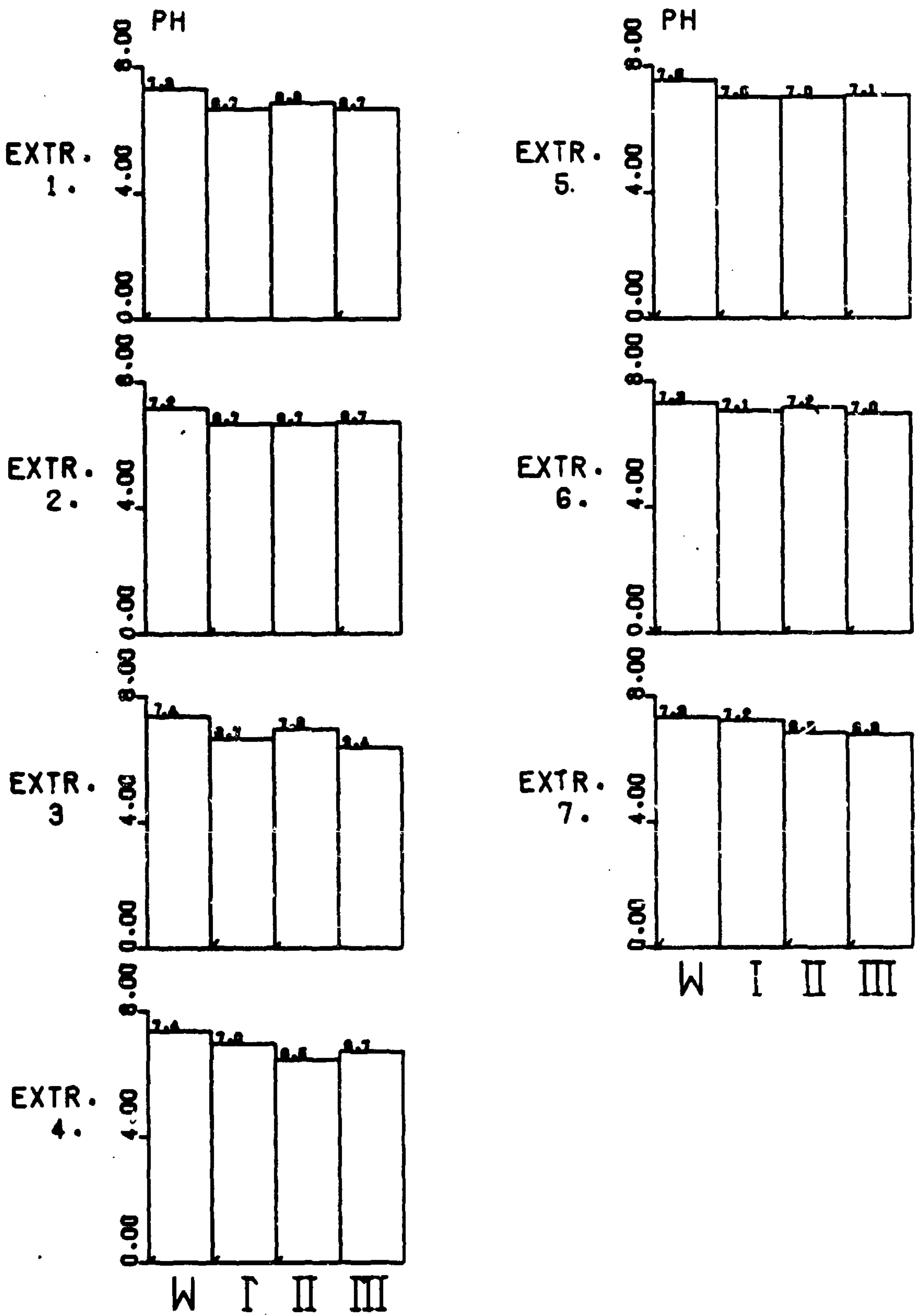


FIGURE 47. pH OF EXTRACT FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

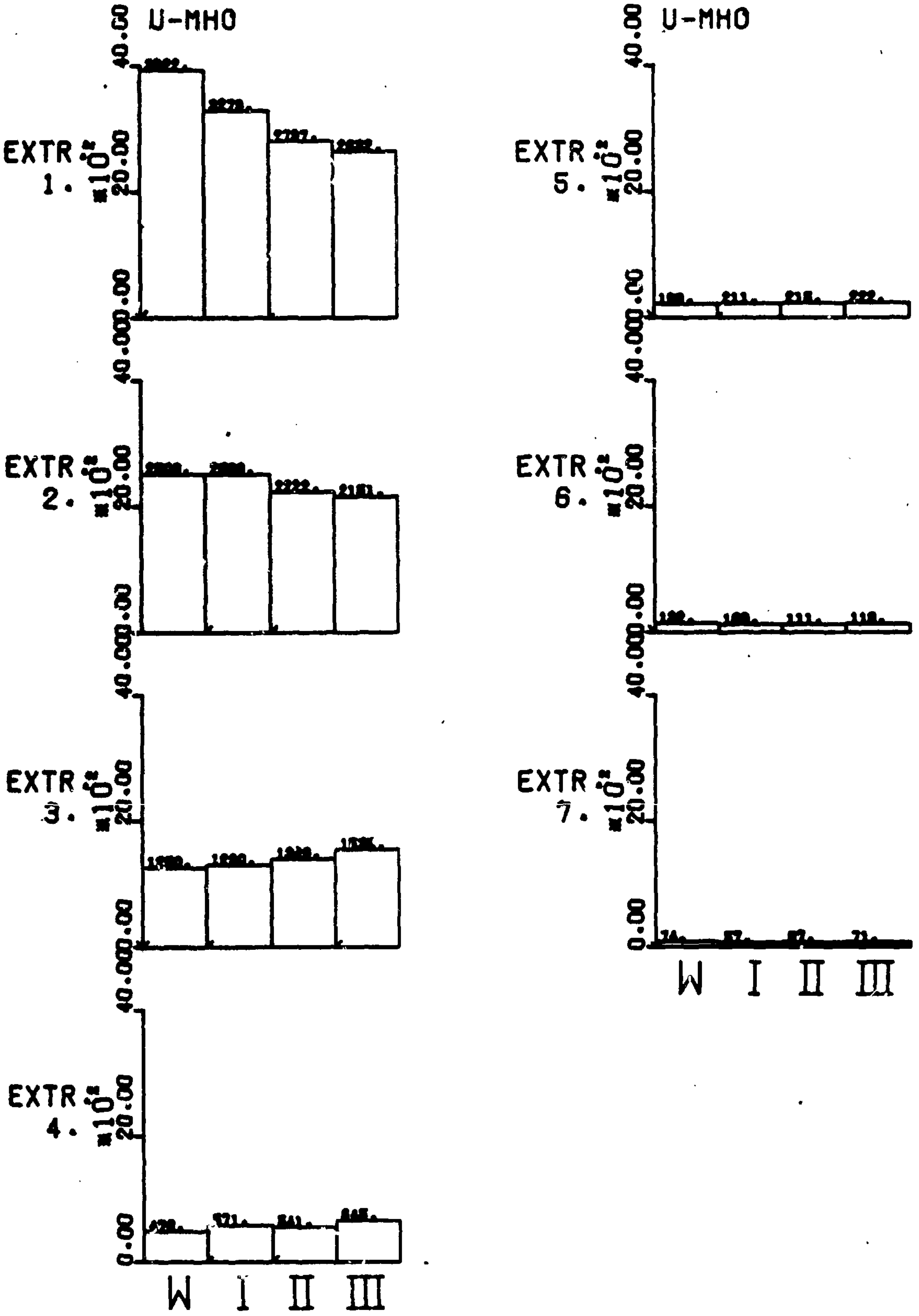


FIGURE 48. CONDUCTANCE OF EXTRACT FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

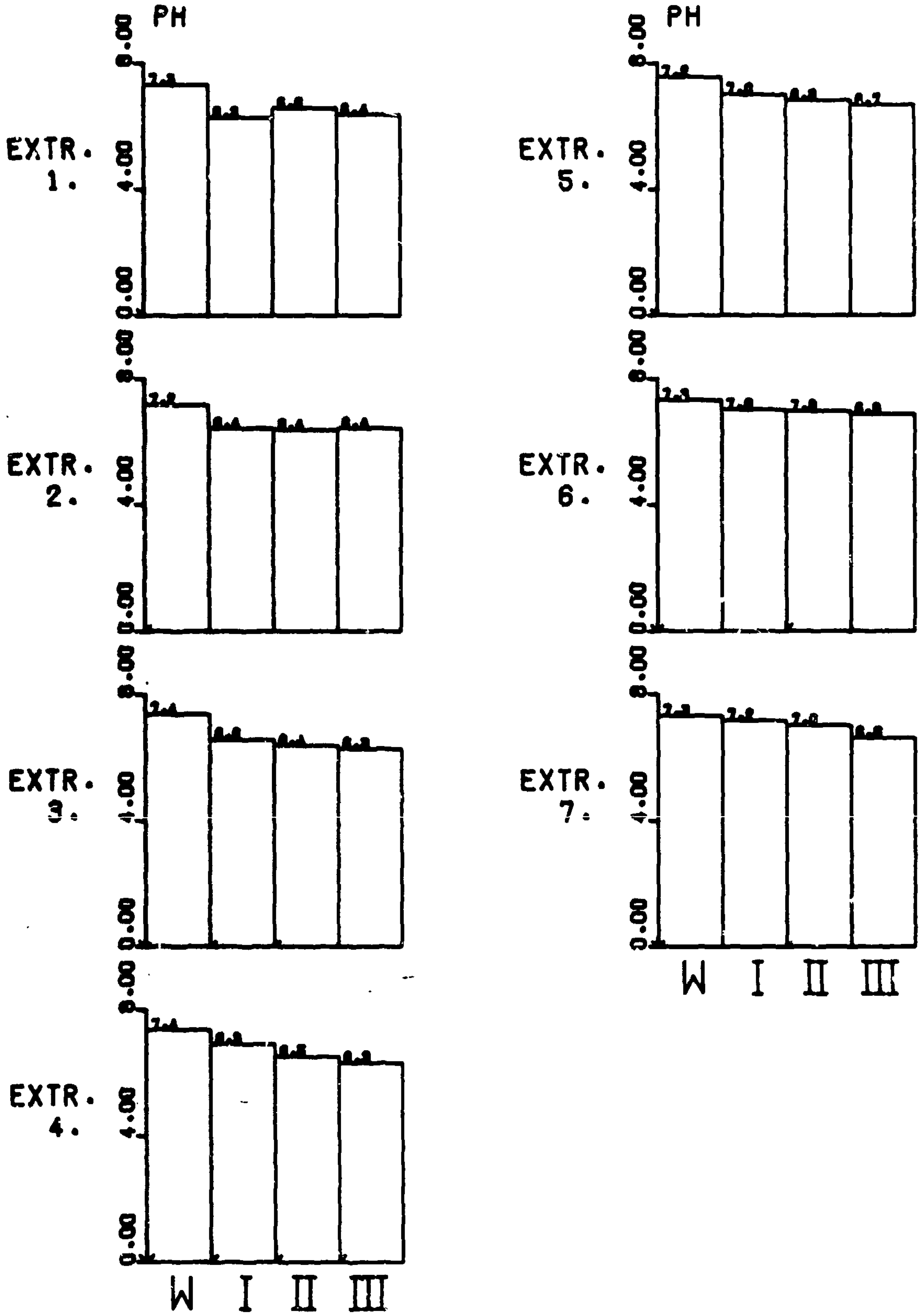


FIGURE 49. pH OF EXTRACT FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

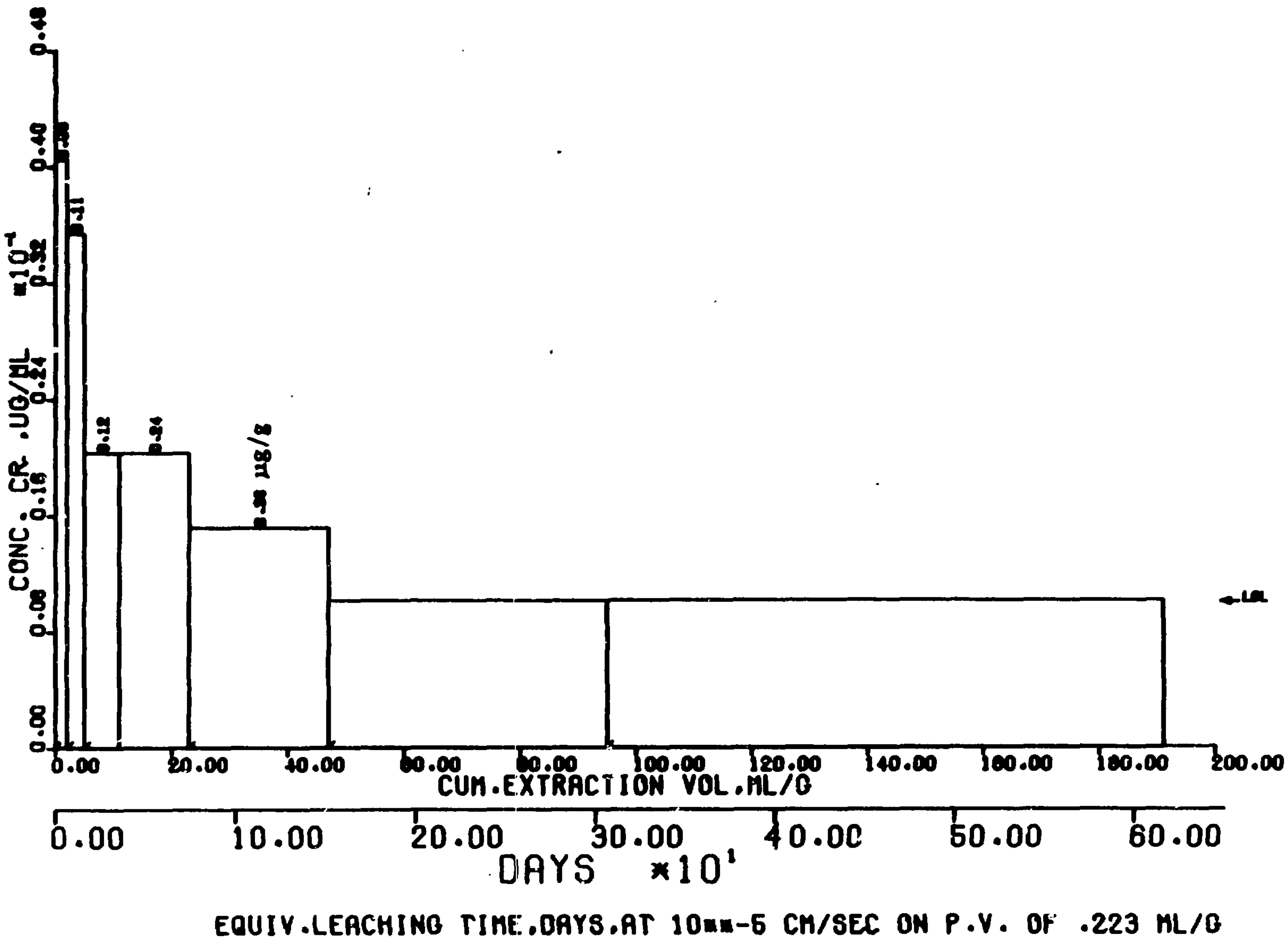


FIGURE 50. EXTRACTION OF CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE.

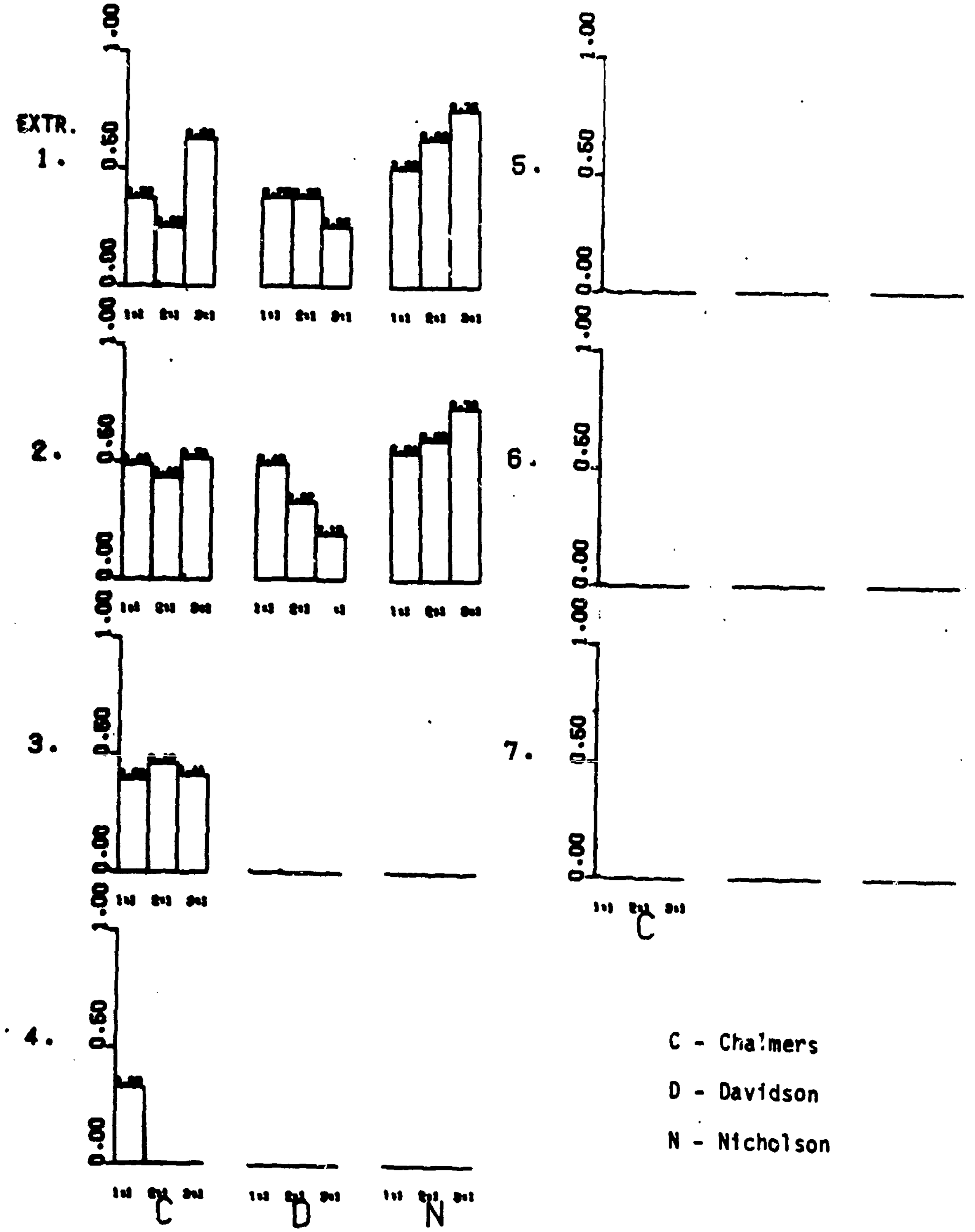


FIGURE 51. COMPARING FRACTION CHROMIUM RETAINED BY SOILS FROM TITANIUM-DIOXIDE PIGMENT WASTE LEACHATE.

TABLE 2[illegible]. CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.04	.08										
	I	.03	.05	.03	.08	.03	.37	.37	.63	555.86	89.90	.60	30.96
	II	.03	.06	-.01	.05	-.01	-.20	-.20	1.20	461.80	89.88	-.17	-9.46
	III	.02	.03	.03	.06	.03	.50	.50	.50	925.09	89.94	1.00	45.00
	I+II			.01	.04	.01	.25	.25	.75	1040.52	89.97	.33	18.43
	I+II+III			.02	.03	.02	.63	.63	.38	8318.50	89.99	1.67	59.04
2	W	.04	.11										
	I	.02	.05	.06	.19	.09	.57	.49	.43	618.06	89.91	2.00	63.43
	II	.02	.05	.00	.10	-.01	.00	-.11	1.00	615.84	89.91	-.22	-12.53
	III	.02	.06	-.02	.11	.02	-.33	.14	1.33	462.30	89.88	.25	14.04
	I+II			.03	.09	.04	.57	.43	.43	2466.02	89.98	1.78	60.64
	I+II+III			.02	.06	.03	.43	.51	.57	4166.00	89.99	1.58	57.72
3	W	.02	.12										
	I	.02	.09	.03	.31	.12	.25	.39	.75	309.36	89.81	1.33	53.13
	II	<.01	<.06	.03	.19	.02	.33	.11	.67	462.38	89.88	.33	18.43
	III	.02	.09	-.03	.17	-.02	-.50	-.09	1.50	307.86	89.81	-.17	-9.46
	I+II			.03	.15	.07	.50	.46	.50	1050.52	89.97	2.33	66.80
	I+II+III			.01	.10	.04	.25	.41	.75	2773.67	89.98	1.39	54.25
4	W	.02	.24										
	I	.02	.10	.06	.55	.18	.25	.33	.75	155.02	89.63	1.00	45.00
	II	<.01	<.12										
	III	<.01	<.12										
	I+II												
	I+II+III												
5	W	.02	.36										
	I	<.01	<.24		.91								
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.40										
	I	<.01	<.40										
	II	.02	.73										
	III	.02	.73										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.77										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

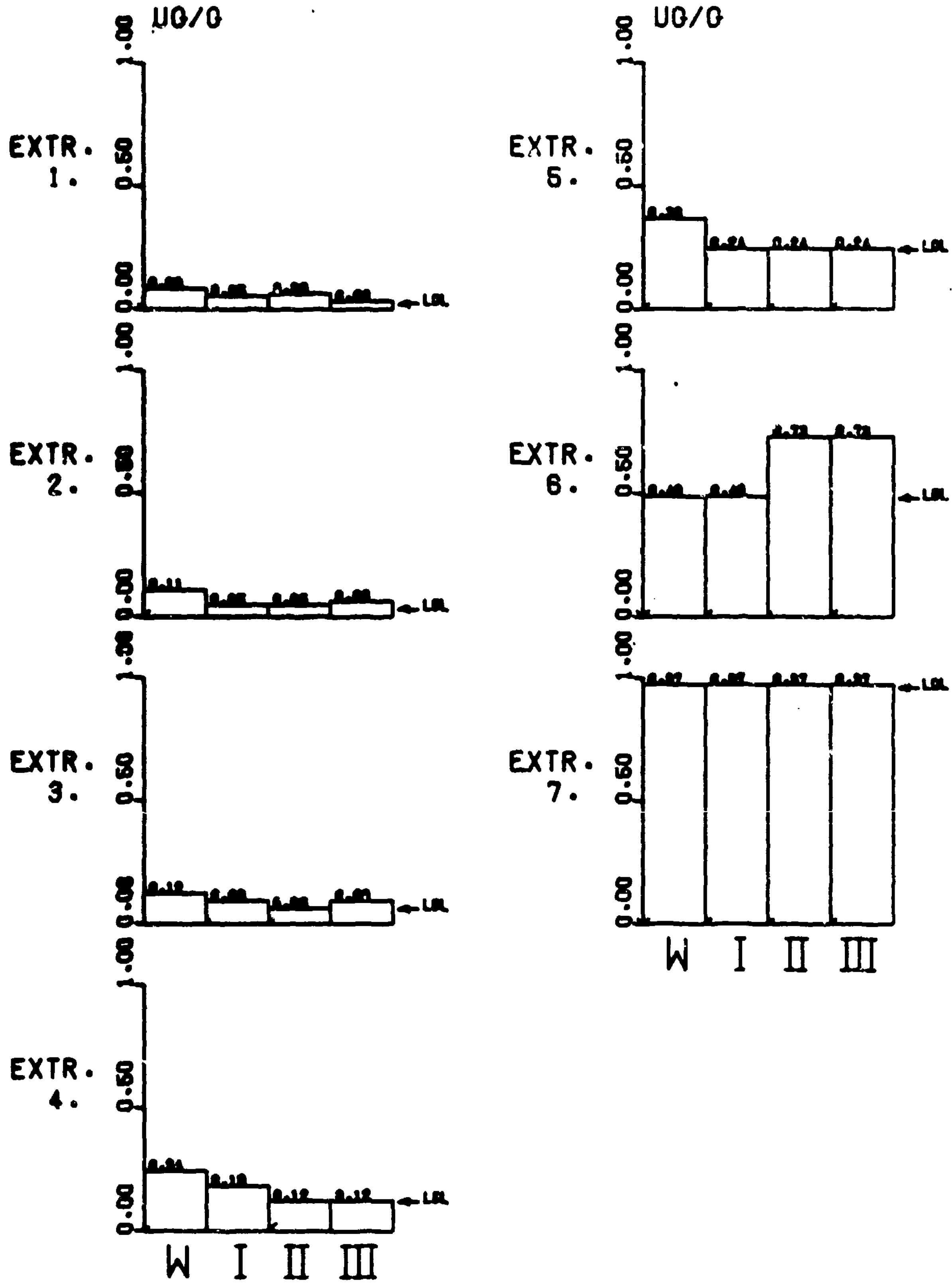


FIGURE 52. WEIGHT OF CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

TABLE 30. CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL. SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL. SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.04	.20										
	I	.03	.05	.03	.08	.03	.37	.37	.63	764.96	89.93	.60	30.96
	II	.03	.05	.00	.05	.60	.00	.00	1.00	764.36	89.93	.00	.00
	III	.03	.06	-.01	.65	-.01	-.20	-.20	1.20	636.00	89.91	-.17	-9.46
	I+II			.02	.04	.02	.38	.38	.63	3058.03	89.98	.60	30.96
	I+II+III			.01	.03	.01	.25	.25	.75	5733.01	89.99	.33	18.43
2	W	.04	.11										
	I	.02	.05	.06	.19	.09	.57	.49	.43	851.20	89.93	2.00	63.43
	II	.03	.08	-.03	.10	-.03	-.67	-.32	1.67	509.17	89.89	-.40	-21.80
	III	.03	.09	-.02	.13	-.03	-.20	-.20	1.20	424.36	89.86	-.20	-15.52
	I+II			.02	.09	.03	.29	.32	.71	2039.00	89.97	.80	38.66
	I+II+III			.01	.06	.01	.14	.19	.86	3822.17	89.99	.39	21.25
3	W	.02	.12										
	I	.03	.10	-.06	.31	.03	-.50	.10	1.50	212.49	89.73	.17	9.46
	II	<.01	<.06										
	III	<.01	<.06										
	I+II												
	I+II+III												
4	W	.02	.24										
	I	<.01	<.12		.55								
	II	<.01	<.12										
	III	.02	.10										
	I+II												
	I+II+III												
5	W	.02	.36										
	I	.02	.36		.91								
	II	.02	.36										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.40										
	I	<.01	<.40										
	II	<.01	<.40										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

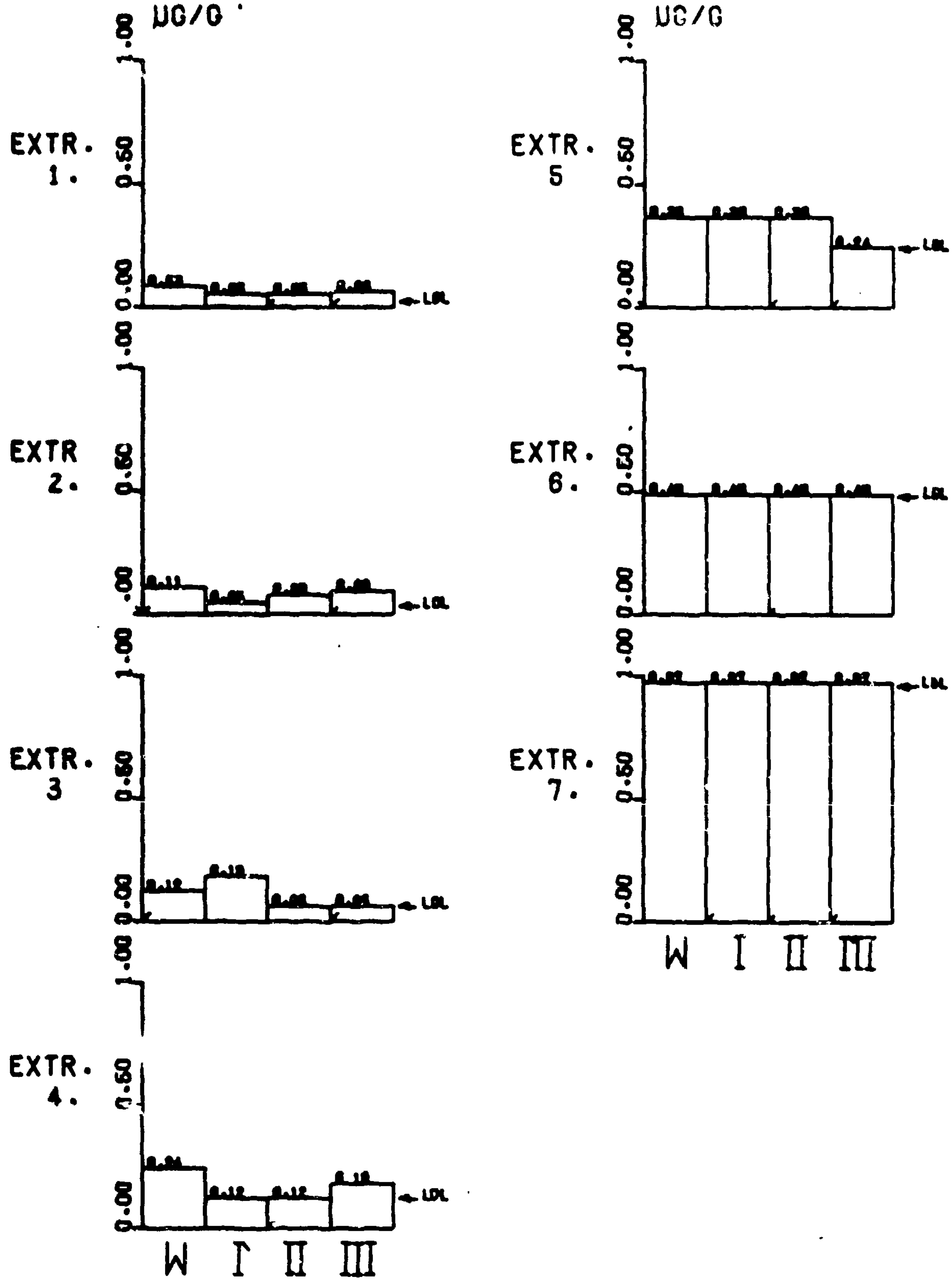


FIGURE 53. WEIGHT OF CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

TABLE 31. CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.04	.08										
	I	.02	.04	.04	.08	.04	.50	.50	.50	817.83	89.93	1.00	45.00
	II	.02	.03	.01	.04	.01	.25	.25	.75	1009.44	89.95	.33	18.43
	III	<.01	<.02	.01	.03	.01	.33	.33	.67	1634.16	89.96	.50	26.57
	I+II			.03	.04	.03	.63	.63	.38	4358.10	89.99	1.67	59.04
	I+II+III			.02	.03	.02	.75	.75	.25	14705.97	90.00	3.00	71.57
2	W	.04	.11										
	I	.02	.05	.06	.19	.10	.57	.54	.43	728.29	89.92	2.22	65.77
	II	.02	.05	.00	.09	.01	.00	.12	1.00	726.29	89.72	.22	12.53
	III	<.01	<.03	.02	.08	.03	.33	.33	.67	1089.94	89.95	.83	39.81
	I+II			.03	.09	.06	.57	.59	.43	2966.73	89.98	2.44	67.75
	I+II+III			.03	.06	.05	.71	.73	.29	9806.40	89.99	4.50	77.47
3	W	.02	.12										
	I	<.01	<.06		.31								
	II	<.01	<.06										
	III	.02	.09										
	I+II												
	I+II+III												
4	W	.02	.24										
	I	.02	.24										
	II	<.01	<.12										
	III	<.01	<.12										
	I+II												
	I+II+III												
5	W	.02	.36										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	.02	.73										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

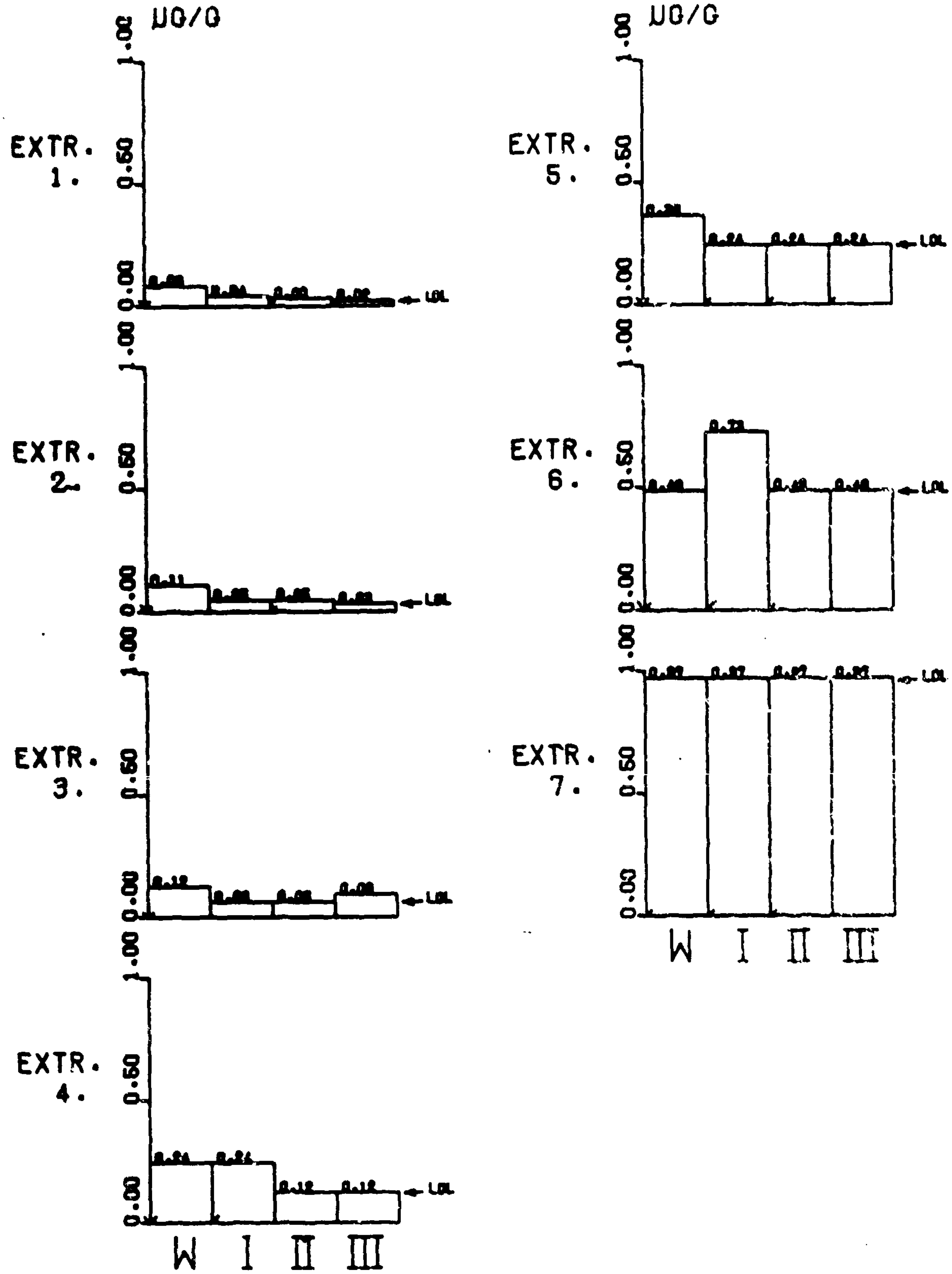


FIGURE 54. WEIGHT OF CHROMIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

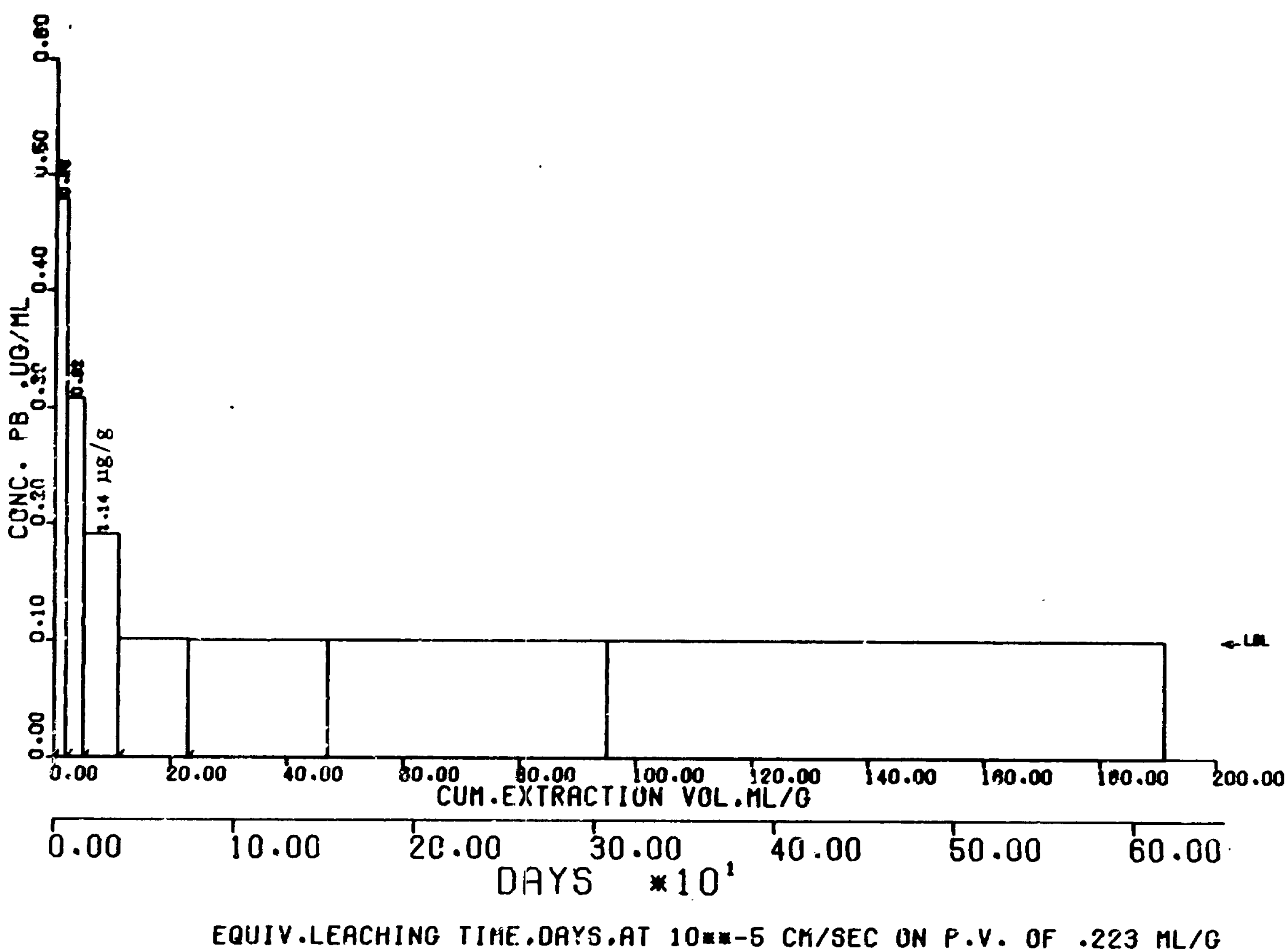


FIGURE 55. EXTRACTION OF LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE.

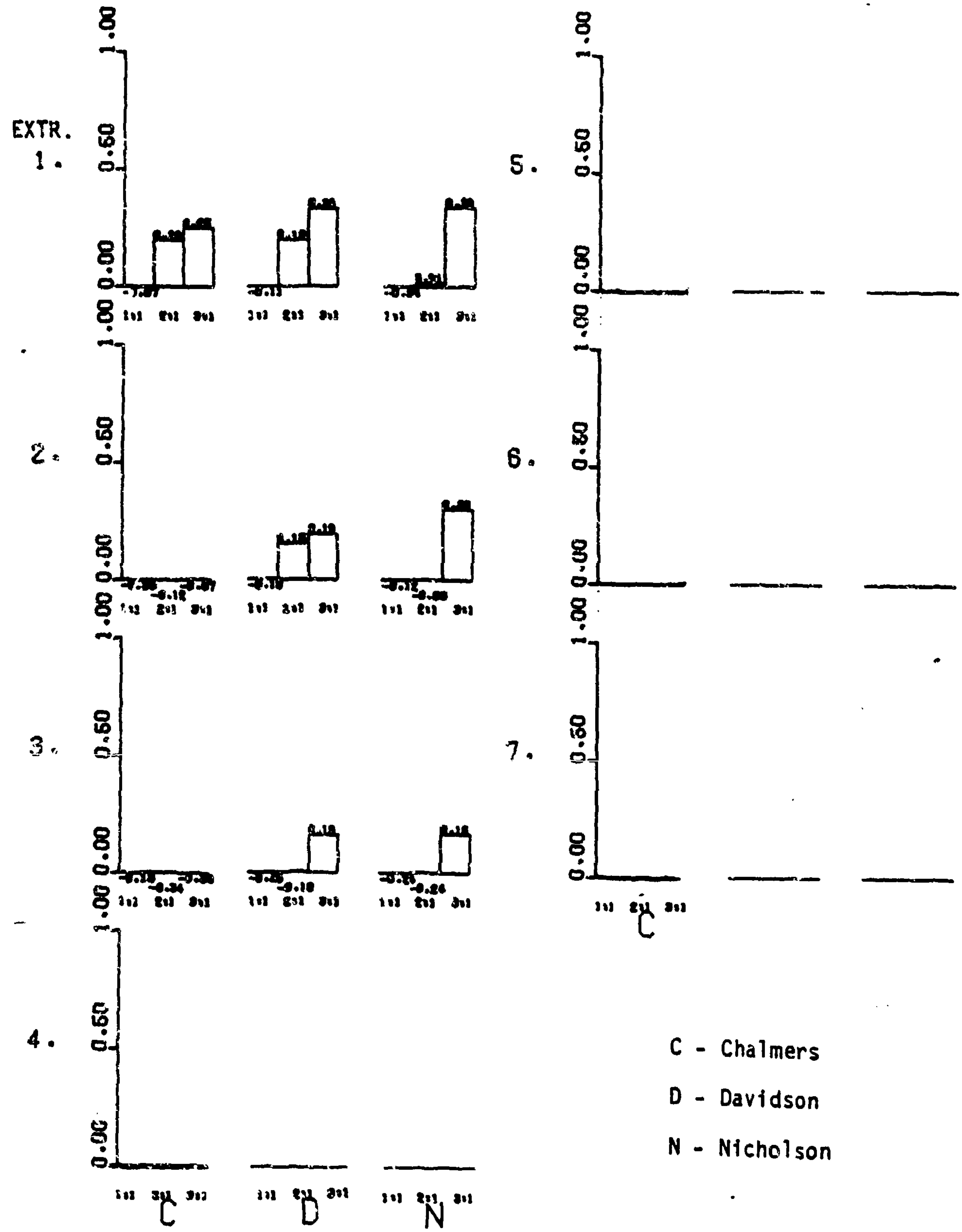


FIGURE 56. COMPARING FRACTION LEAD RETAINED BY SOILS FROM TITANIUM-DIOXIDE PIGMENT WASTE LEACHATE.

TABLE 32. LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.40	.96										
	I	.51	1.02	-.06	.96	-.06	-.07	-.07	1.07	96.25	89.40	-.06	-3.51
	II	.39	.77	.25	1.02	.25	.25	.25	.75	127.95	89.55	.33	18.01
	III	.36	.72	.05	.77	.05	.06	.06	.94	136.46	89.58	.07	3.93
	I+II			.09	.40	.09	.20	.20	.80	510.76	89.89	.24	13.71
	I+II+III			.08	.32	.08	.25	.25	.75	1227.87	89.95	.33	18.23
2	W	.31	.92										
	I	.40	1.43	-.50	1.88	-.57	-.55	-.30	1.55	68.66	89.17	-.40	-21.64
	II	.44	1.33	.09	2.45	.34	.06	.14	.94	74.11	89.23	.26	14.45
	III	.43	1.29	.04	2.11	.09	.03	.04	.97	76.26	89.25	.07	4.01
	I+II			-.21	.94	-.11	-.44	-.12	1.44	295.24	89.81	-.17	-9.47
	I+II+III			-.12	.63	-.04	-.40	-.07	1.40	685.64	89.92	-.10	-5.82
3	W	.19	1.14										
	I	.16	.99	.16	3.03	-.41	.14	-.13	.86	99.33	89.42	-.41	-22.40
	II	.33	1.96	-.97	3.44	-.63	-.99	-.18	1.99	49.90	88.85	-.32	-17.83
	III	.37	2.20	-.24	4.07	-.15	-.12	-.04	1.12	44.66	88.72	-.07	-3.91
	I+II			-.41	1.51	-.52	-.71	-.34	1.71	200.36	89.71	-.53	-27.91
	I+II+III			-.35	1.01	-.40	-.92	-.39	1.92	401.98	89.86	-.54	-28.38
4	W	<.10	<1.21										
	I	.22	2.65										
	II	.20	2.38										
	III	.17	2.10										
	I+II												
	I+II+III												
5	W	<.10	<2.40										
	I	.19	4.57										
	II	<.10	<2.40										
	III	.11	2.73										
	I+II												
	I+II+III												
6	W	<.10	<4.80										
	I	.11	5.22										
	II	.16	7.45										
	III	.13	6.20										
	I+II												
	I+II+III												
7	W	<.10	<9.60										
	I	<.10	<9.60										
	II	<.10	<9.60										
	III	<.10	<9.60										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the occurrence of values below the detection limit.

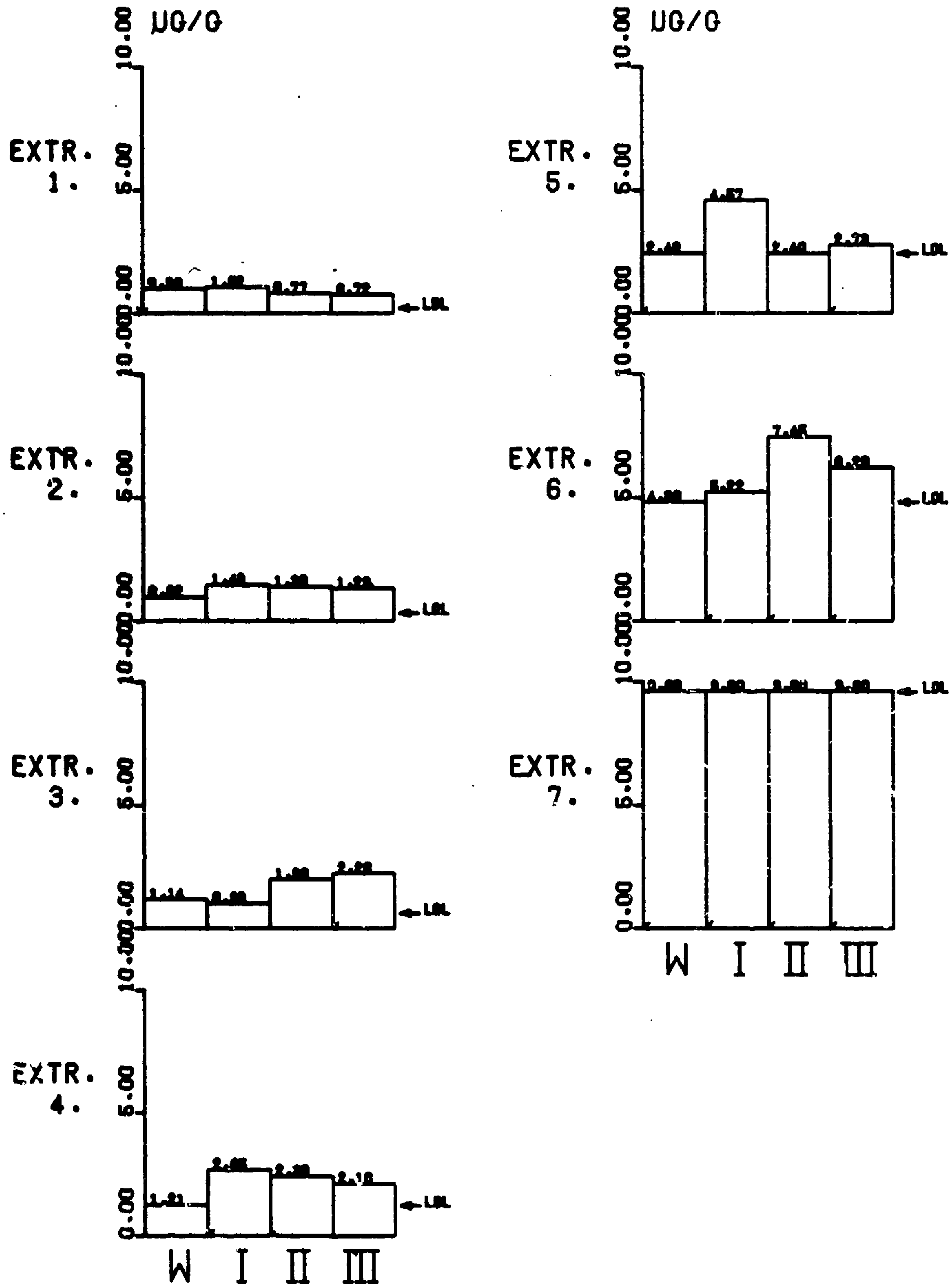


FIGURE 57. WEIGHT OF LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

TABLE 33. LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.48	.96										
	I	.53	1.07	-.11	.96	-.11	-.11	-.11	1.11	144.47	89.60	-.10	-5.64
	II	.39	.77	.29	1.07	.29	.27	.27	.73	199.37	89.71	.38	20.63
	III	.32	.65	.13	.77	.13	.17	.17	.83	238.75	89.76	.20	11.24
	I+II			.09	.48	.09	.19	.19	.81	796.22	89.93	.24	13.52
	I+II+III			.10	.32	.10	.33	.33	.67	2147.43	89.97	.49	25.97
2	W	.31	.92										
	I	.37	1.11	-.19	1.88	-.29	-.21	-.16	1.21	138.17	89.59	-.26	-14.83
	II	.28	.83	.28	2.18	.58	.26	.26	.74	186.74	89.69	.70	34.83
	III	.29	.88	-.05	1.60	.08	-.06	.05	1.06	175.30	89.67	.09	5.02
	I+II			.05	.94	.14	.10	.15	.90	744.50	89.92	.34	18.78
	I+II+III			.01	.63	.12	.05	.19	.95	1577.31	89.96	.41	22.20
3	W	.19	1.14										
	I	.27	1.59	-.45	3.03	-.74	-.39	-.25	1.39	96.09	89.40	-.47	-25.03
	II	.29	1.71	-.12	3.77	.46	-.07	.12	1.07	90.11	89.36	.27	14.92
	III	.17	1.03	.69	3.32	.76	.40	.23	.60	150.64	89.62	.74	36.63
	I+II			-.28	1.51	-.14	-.50	-.10	1.50	359.19	89.84	-.17	-9.54
	I+II+III			.04	1.01	.16	.10	.16	.90	1349.50	89.96	.46	24.85
4	W	<.10	<1.21										
	I	.19	2.24										
	II	.14	1.67										
	III	.20	2.45										
	I+II												
	I+II+III												
5	W	<.10	<2.40										
	I	.22	5.35										
	II	.20	4.83										
	III	.18	4.38										
	I+II												
	I+II+III												
6	W	<.10	<4.80										
	I	<.10	<4.80										
	II	.14	6.80										
	III	.10	4.96										
	I+II												
	I+II+III												
7	W	<.10	<9.60										
	I	.14	13.09										
	II	.20	18.74										
	III	<.10	<9.66										
	I+II												
	I+II+III												

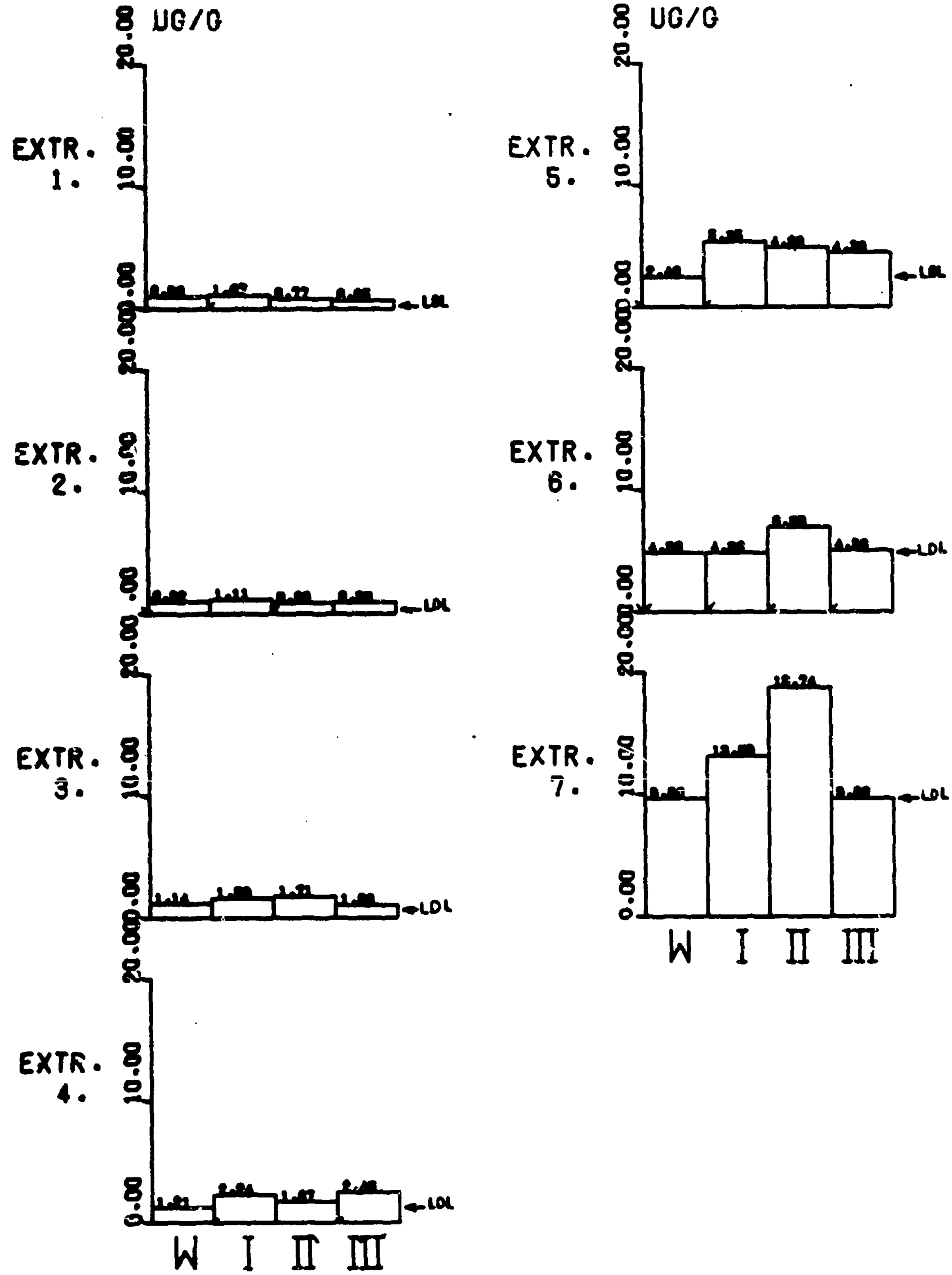


FIGURE 58. WEIGHT OF LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

TABLE 34. LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	0	.40	.96										
	I	.50	1.00	-.04	.96	-.04	-.04	-.04	1.04	99.31	89.42	-.04	-2.43
	II	.47	.75	.06	1.00	.06	.06	.06	.94	105.30	89.46	.06	3.39
	III	.32	.64	.31	.95	.31	.33	.33	.67	156.40	89.63	.48	25.72
	I+II			.01	.40	.01	.01	.01	.99	420.96	89.86	.01	.82
	I+II+III			.11	.32	.11	.33	.33	.67	1403.79	89.96	.50	26.70
2	0	.31	.92										
	I	.37	1.11	-.19	1.00	-.23	-.21	-.12	1.21	89.27	89.36	-.21	-11.80
	II	.33	.99	.12	2.12	.18	.11	.09	.89	100.95	89.43	.18	10.37
	III	.23	.68	.30	1.93	.61	.31	.32	.69	146.63	89.61	.90	41.87
	I+II			-.03	.94	-.03	-.07	-.03	1.07	403.03	89.86	-.05	-3.00
	I+II+III			.00	.63	.19	.26	.30	.74	1312.46	89.96	.82	39.30
3	0	.19	1.14										
	I	.27	1.65	-.50	3.03	-.74	-.44	-.24	1.44	59.95	89.04	-.45	-24.00
	II	.30	1.03	-.10	3.76	.00	-.11	.00	1.11	54.60	88.95	.00	.05
	III	.20	1.21	.62	3.76	1.23	.34	.33	.66	83.43	89.31	1.02	45.55
	I+II			-.34	1.51	-.37	-.60	-.24	1.60	217.50	89.74	-.40	-21.91
	I+II+III			-.02	1.01	.17	-.06	.16	1.06	742.06	89.92	.41	22.35
4	0	<.10	<1.21										
	I	.23	2.75										
	II	.22	2.60										
	III	.15	1.79										
	I+II												
	I+II+III												
5	0	<.10	<2.40										
	I	<.10	<2.40										
	II	.16	3.73										
	III	.15	3.62										
	I+II												
	I+II+III												
6	0	<.10	<4.80										
	I	<.10	<4.80										
	II	.14	6.59										
	III	<.10	<4.80										
	I+II												
	I+II+III												
7	0	<.10	<9.60										
	I	.15	14.21										
	II	.13	12.13										
	III	.11	10.41										
	I+II												
	I+II+III												

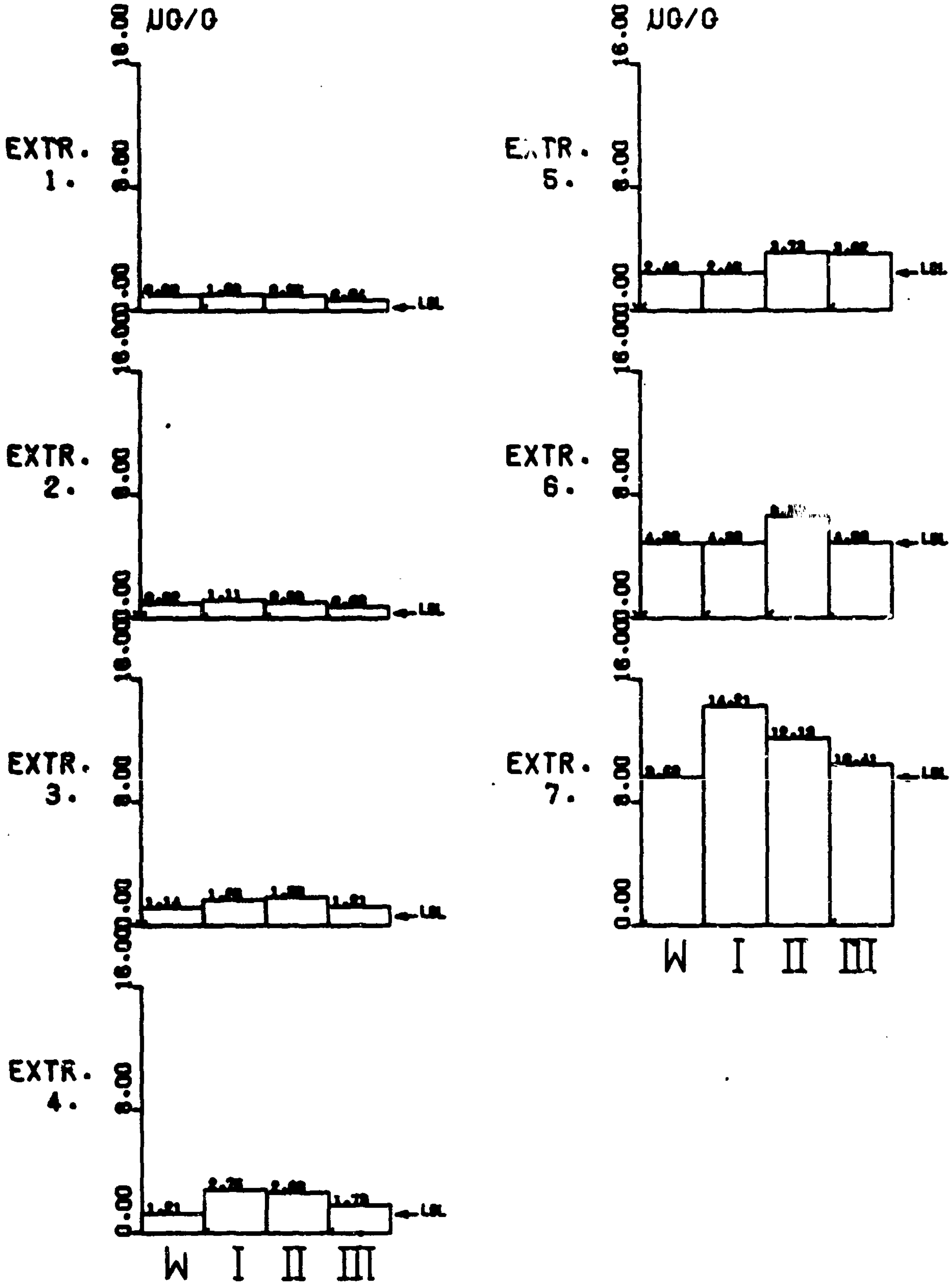


FIGURE 59. WEIGHT OF LEAD FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

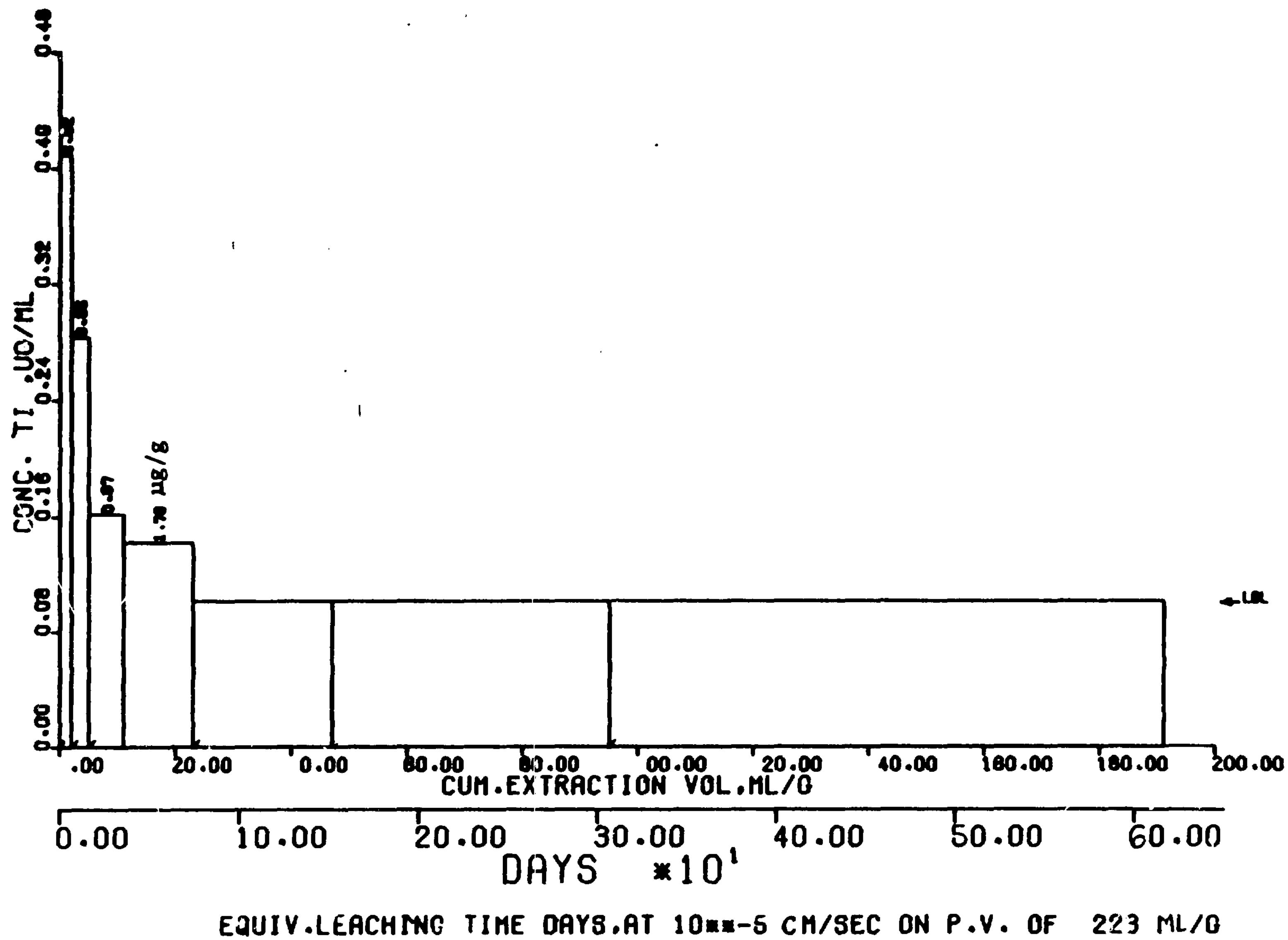


FIGURE 60. EXTRACTION OF TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE.

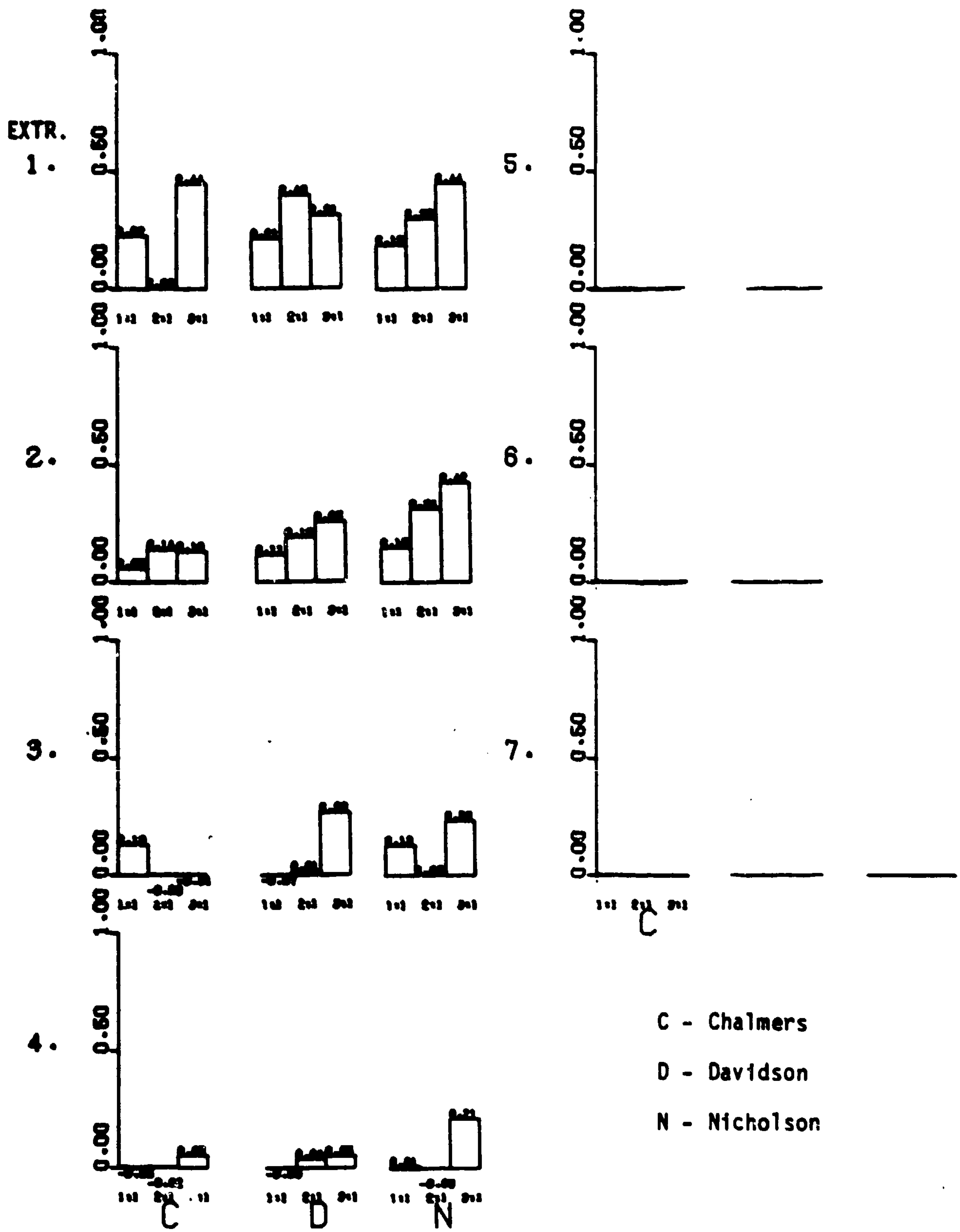


FIGURE 61. COMPARING FRACTION TITANIUM RETAINED BY SOILS FROM TITANIUM-DIOXIDE PIGMENT WASTE LEACHATE.

TABLE 35. TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.41	.82										
	I	.32	.64	.18	.82	.18	.22	.22	.78	163.73	89.65	.29	15.95
	II	.41	.82	-.18	.64	-.18	-.29	-.29	1.29	126.90	89.55	-.22	-12.53
	III	.23	.46	.36	.82	.36	.44	.44	.56	229.62	89.75	.80	38.66
	I+II			.00	.41	.00	.00	.00	1.00	508.50	89.89	.00	.00
	I+II+III			.12	.27	.12	.44	.44	.56	2040.21	89.97	.80	38.66
2	W	.28	.85										
	I	.31	.94	-.09	1.67	.09	-.11	.05	1.11	110.82	89.48	.10	5.53
	II	.21	.62	.32	1.50	.14	.34	.09	.66	167.65	89.66	.22	12.38
	III	.33	1.00	-.38	1.44	-.02	-.61	-.01	1.61	104.00	89.45	-.02	-.87
	I+II			.11	.83	.11	.27	.14	.73	670.09	89.91	.37	20.10
	I+II+III			-.05	.56	.07	-.10	.13	1.10	936.31	89.94	.21	11.90
3	W	.16	.97										
	I	.12	.73	.24	2.64	.33	.25	.13	.75	143.47	89.60	.46	24.62
	II	.23	1.36	-.64	2.30	-.50	-.87	-.22	1.87	75.91	89.25	-.37	-20.14
	III	.20	1.21	.15	2.80	.14	.11	.05	.89	85.92	89.33	.11	6.42
	I+II			-.20	1.32	-.00	-.41	-.36	1.41	304.97	99.81	-.12	-6.97
	I+II+III			-.00	.80	-.01	-.25	-.01	1.25	772.25	89.93	-.03	-1.43
4	W	.14	1.70										
	I	.19	2.24	-.55	4.33	-.21	-.32	-.05	1.32	46.29	88.76	-.09	-5.40
	II	.14	1.64	.61	4.55	.11	.27	.02	.73	63.63	89.10	.06	3.71
	III	.12	1.45	.18	4.44	.32	.11	.07	.89	71.73	89.20	.22	12.34
	I+II			.03	2.17	-.05	.04	-.02	.96	254.18	89.77	-.06	-3.71
	I+II+III			.08	1.44	.07	.14	.05	.86	643 71	89.91	.15	8.30
5	W	<.10	<2.42										
	I	.22	5.21										
	II	<.10	<2.42										
	III	.11	2.67										
	I+II												
	I+II+III												
6	W	<.10	<4.05										
	I	<.10	<4.05										
	II	.20	9.70										
	III	.17	8.24										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	<.10	<9.70										
	II	<.10	<9.70										
	III	<.10	<9.70										
	I+II												
	I+II+III												

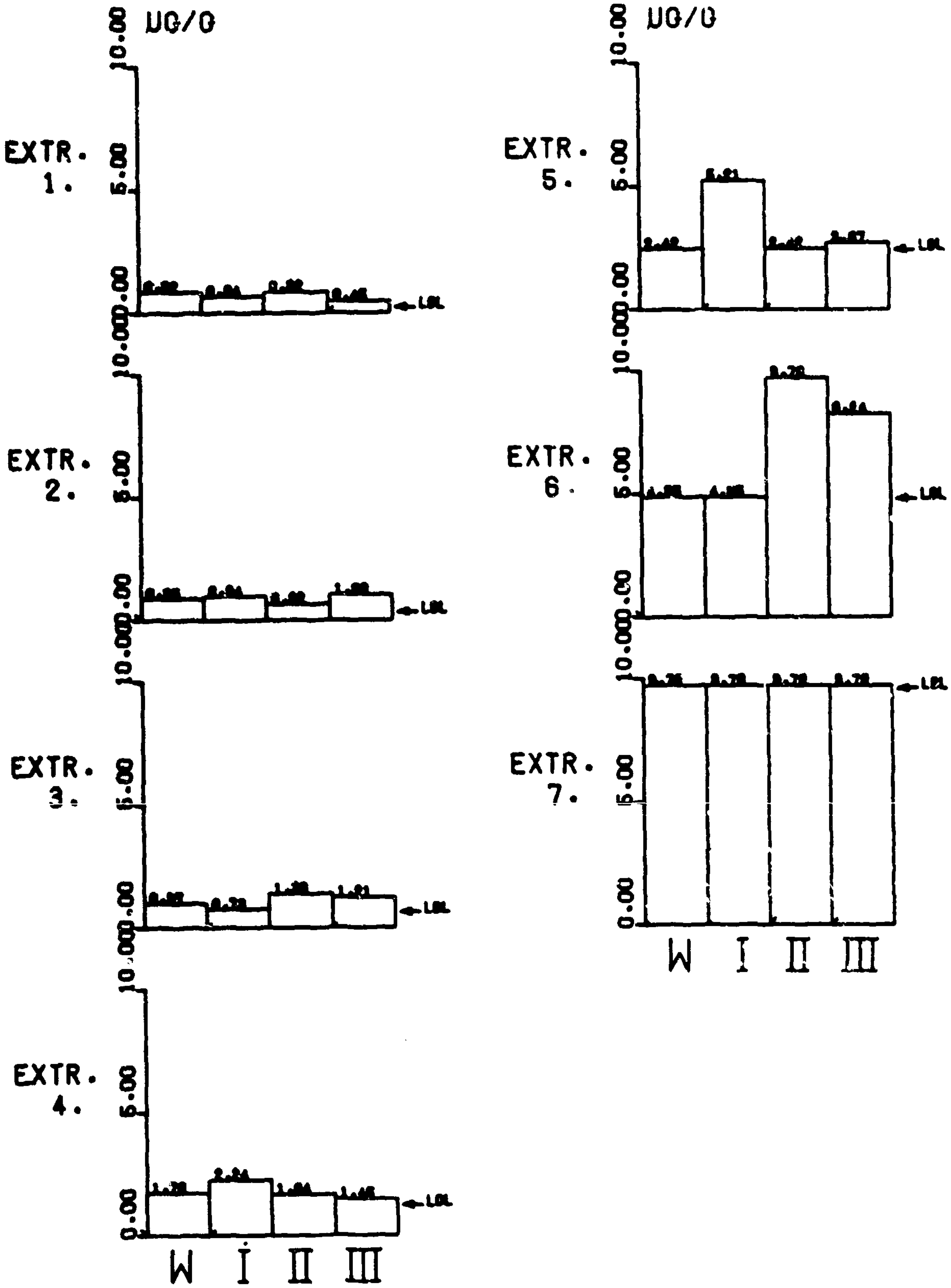


FIGURE 62. WEIGHT OF TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON CHALMERS SOIL.

TABLE 36. TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.41	.82										
	I	.32	.65	.17	.82	.17	.21	.21	.79	2023.78	89.97	.27	14.88
	II	.25	.49	.15	.65	.15	.23	.23	.77	2643.26	89.98	.31	17.02
	III	.28	.57	-.07	.49	-.07	-.14	-.14	1.14	2312.46	89.98	-.12	-7.13
	I+II			.16	.41	.16	.40	.40	.60	10572.49	89.99	.65	33.15
	I+II+III			.08	.27	.08	.31	.31	.69	20813.74	90.00	.45	24.06
2	W	.38	.85										
	I	.38	.83	.02	1.67	.19	.02	.11	.98	1569.98	89.96	.22	12.64
	II	.29	.86	-.03	1.48	.12	-.04	.08	1.04	1514.82	89.96	.14	7.99
	III	.23	.68	.18	1.36	.11	.21	.08	.79	1918.75	89.97	.16	9.26
	I+II			-.01	.83	.15	-.02	.18	1.02	6059.07	89.99	.36	19.63
	I+II+III			.06	.56	.14	.20	.25	.80	17267.94	90.00	.61	31.58
3	W	.16	.97										
	I	.22	1.33	-.36	2.64	-.18	-.38	-.07	1.38	980.97	89.94	-.13	-7.55
	II	.21	1.24	.09	2.81	.21	.07	.08	.93	1053.06	89.95	.17	9.69
	III	.12	.70	.55	2.60	.66	.44	.25	.56	1077.83	89.97	.94	43.29
	I+II			-.14	1.32	.02	-.20	.01	1.28	4211.57	89.99	.03	1.63
	I+II+III			.09	.80	.23	.28	.26	.72	16892.94	90.00	.99	44.79
4	W	.14	1.70										
	I	.16	1.80	-.10	4.33	-.36	-.11	-.08	1.11	696.07	89.92	-.19	-10.81
	II	.13	1.50	.30	4.69	.52	.16	.11	.84	830.49	89.93	.33	18.10
	III	.10	2.10	-.61	4.10	.05	-.38	.01	1.38	599.58	89.90	.02	1.33
	I+II			.06	2.17	.08	.07	.04	.93	3320.74	89.98	.10	5.67
	I+II+III			-.16	1.44	.07	-.29	.05	1.29	5396.13	89.99	.09	5.42
5	W	<.10	<2.42										
	I	.19	4.40										
	II	.18	4.24										
	III	.17	4.00										
	I+II												
	I+II+III												
6	W	<.10	<4.05										
	I	<.10	<4.05										
	II	.13	6.06										
	III	.14	6.79										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	.13	12.60										
	II	.11	10.67										
	III	<.10	<9.70										
	I+II												
	I+II+III												

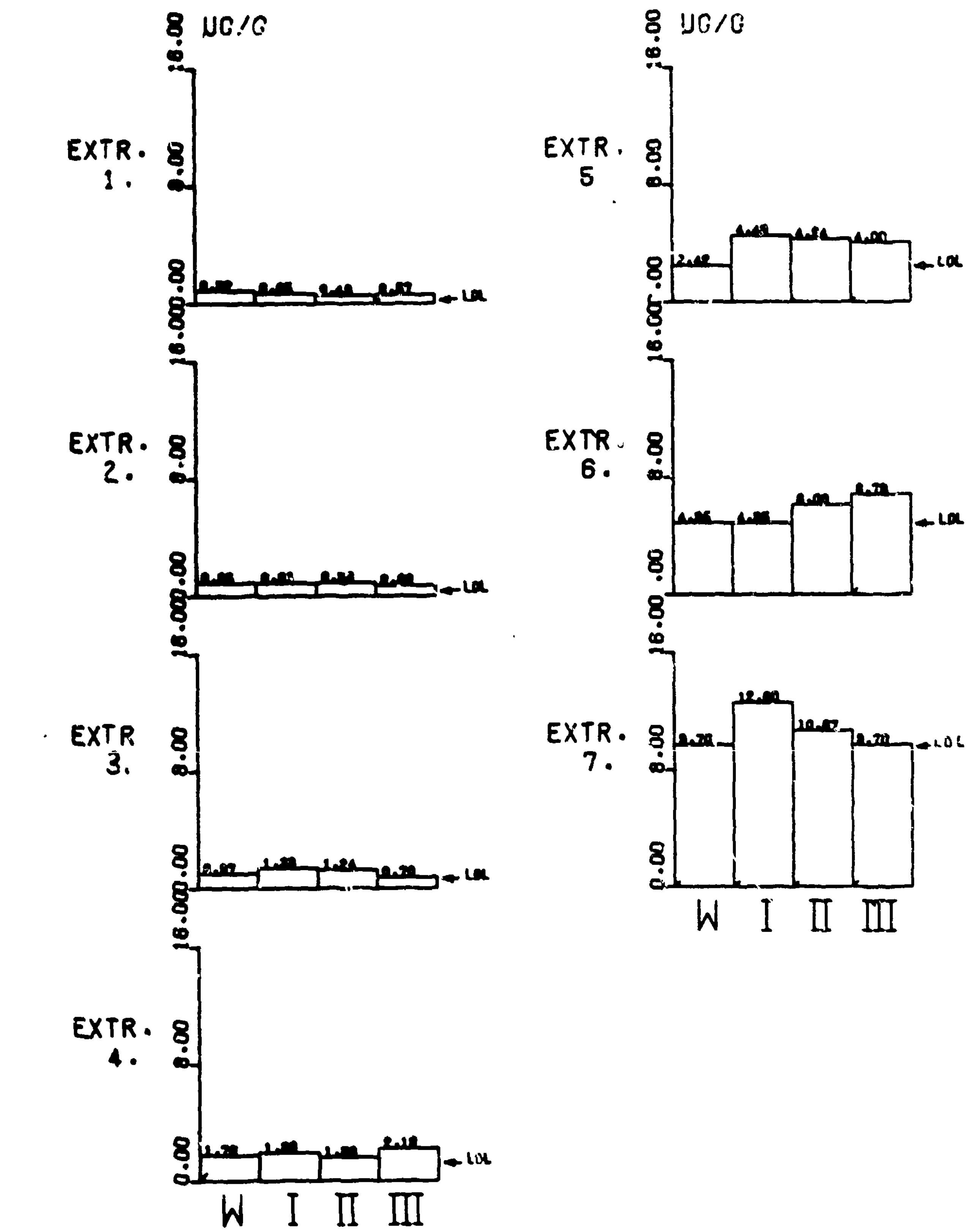


FIGURE 63. WEIGHT OF TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON DAVIDSON SOIL.

TABLE 37. TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.41	.82										
	I	.33	.67	.15	.82	.15	.1[illegible]	.19	.81	177.24	89.69	.23	12.80
	II	.29	.58	.09	.67	.09	.14	.14	.86	205.13	89.72	.16	8.97
	III	.23	.45	.12	.58	.12	.21	.21	.79	259.89	89.78	.27	14.93
	I+II			.12	.41	.12	.30	.30	.70	820.29	89.93	.42	22.83
	I+II+III			.12	.27	.12	.44	.44	.56	2337.43	89.98	.86	38.66
2	W	.28	.85										
	I	.25	.76	.09	1.67	.24	.11	.15	.89	156.10	89.63	.32	17.74
	II	.19	.58	.18	1.42	.27	.24	.19	.76	205.44	89.72	.47	25.35
	III	.17	.52	.06	1.15	.26	.11	.16	.89	229.43	89.75	.35	19.44
	I+II			.14	.83	.26	.32	.31	.68	820.77	89.93	.89	41.82
	I+II+III			.11	.56	.23	.39	.42	.61	2063.09	89.97	1.35	53.53
3	W	.16	.97										
	I	.15	.88	.09	2.64	.33	.09	.13	.91	134.67	89.57	.38	20.77
	II	.25	1.48	-.61	2.30	-.33	-.69	-.14	1.69	79.25	89.28	-.22	-12.65
	III	.18	1.06	.42	2.64	.61	.29	.23	.71	111.84	89.49	.57	29.74
	I+II			-.26	1.32	.00	-.53	.00	1.53	317.91	89.82	.00	.00
	I+II+III			-.03	.88	.20	-.09	.23	1.09	1001.99	89.94	.57	29.74
4	W	.14	1.70										
	I	.17	2.00	-.30	4.33	.03	-.18	.01	1.18	59.02	89.03	.02	.87
	II	.15	1.82	.18	4.30	-.15	.09	-.04	.91	64.82	89.12	-.08	-4.76
	III	.12	1.39	.42	4.45	1.03	.23	.23	.77	85.40	89.33	.74	36.47
	I+II			-.06	2.17	-.06	-.07	-.03	1.07	259.56	89.78	-.07	-3.81
	I+II+III			.10	1.44	.30	.18	.21	.82	762.60	89.92	.65	33.11
5	W	<.10	<2.42										
	I	<.10	<2.42										
	II	.19	4.48										
	III	<.10	<2.42										
	I+II												
	I+II+III												
6	W	<.10	<4.85										
	I	.12	5.58										
	II	.16	7.51										
	III	.11	5.09										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	.15	14.06										
	II	.16	15.51										
	III	.12	11.64										
	I+II												
	I+II+III												

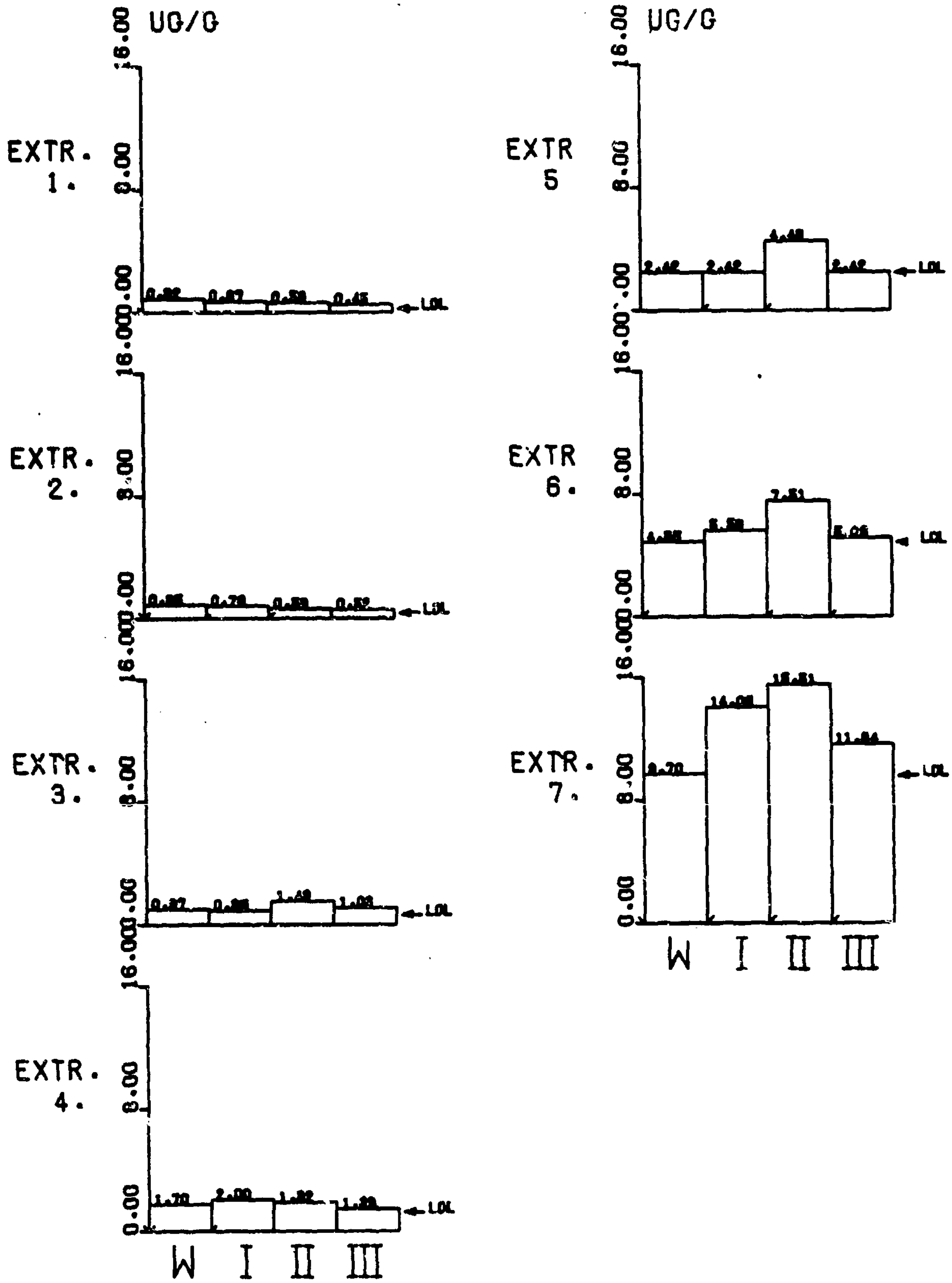


FIGURE 64. WEIGHT OF TITANIUM FROM TITANIUM-DIOXIDE PIGMENT WASTE ON NICHOLSON SOIL.

HYDROFLUORIC ACID PRODUCTION WASTE

Producing hydrofluoric acid by treating fluorspar with concentrated sulfuric acid yields a strongly acid waste. Normally this residue is neutralized before disposal. However, the unneutralized waste was employed in this work so as to study the effect of a strongly acidic waste upon these soils. The measurements listed in Table 38 show that some components readily dissolved to give a solution of quite low pH. Figures 66, 68, and 70 show that passing this extract through the soils reduced the hydrogen ion concentration by about two orders of magnitude in the last several extractions. Figures 65, 67, and 69 show that the materials dissolved in the extract are removed to a large extent by passage through any of the three soils.

TABLE 38. LEACHABILITY OF HYDROFLUORIC ACID PRODUCTION WASTE

Element	Initial Conc. (μg/ml)	When Concentration Levels Off				Total Weight Extracted (μg/g waste)	Percentage Extracted
		Conc. (μg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days		
F	970.	2.4	7	190	620	2,760.	56.

Measurement	Initial	Final	Estim.Tot.Extr. (μ equiv/g)
Conduct. (μ mho)	33,300.	1786.	4480.
pH	2.2	3.7	

Fluorine

The concentration of fluoride ions was high in the first extract (970 μg/ml), dropped 1.6 orders of magnitude by the second extraction, and then leveled off to a concentration of 2.4 μg/ml in the seventh extract (Figure 71). A total of 2,760 μg fluorine was extracted per gram, which represents 56 percent of that available in the waste sample.

The data in Tables 39, 40, and 41 and presented in Figures 72 to 75 show that all three soils are initially very good at retaining fluoride ions from this extract, and allow only one to three percent to penetrate. However, the column of data giving the fraction retained from the solution for each extraction shows a consistent loss of fluorides from all three soils beginning with the fourth extraction. By the seventh extraction, the cumulative retention of Chalmers soil dropped to 59 percent and Nicholson to 54 percent, while Davidson soil was able to retain 72 percent of the total fluorine-containing challenge.

Summary

The uneutralized sample of hydrofluoric acid production waste yielded highly acidic extracts containing large concentrations of fluoride ion. By the completion of the seventh extraction, 56 percent of the available fluorine had been leached out of the waste. The soils were initially very efficient in removing the fluoride ions but in the later stages of the exposure to this leachate, the soils were giving up substantial amounts of fluoride previously retained from the solution.

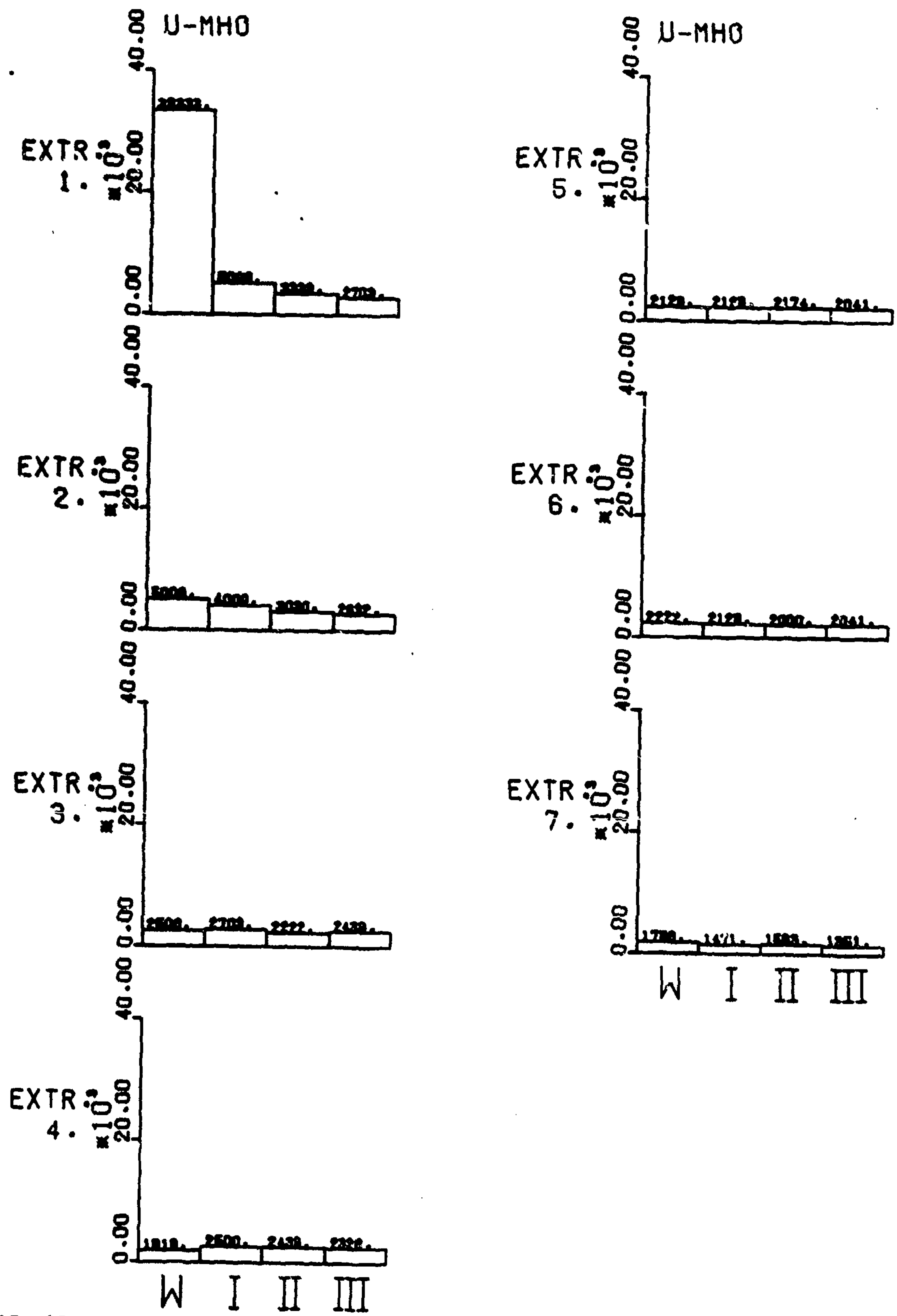


FIGURE 65. CONDUCTANCE OF EXTRACT FROM HYDROFLUORIC ACID WASTE ON CHALMERS SOIL.

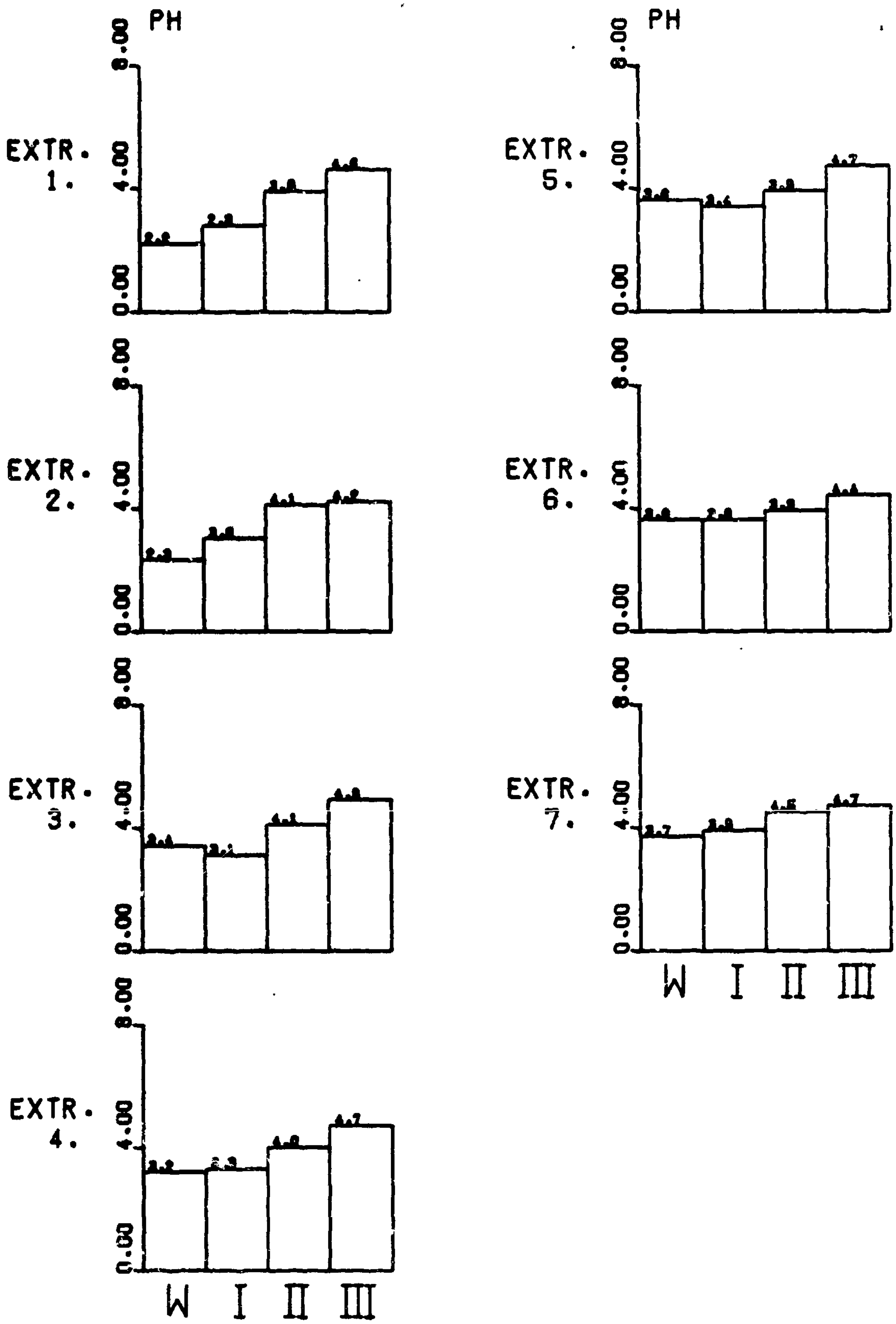


FIGURE 66. pH OF EXTRACT FROM HYDROFLUORIC ACID WASTE ON CHALMERS SOIL.

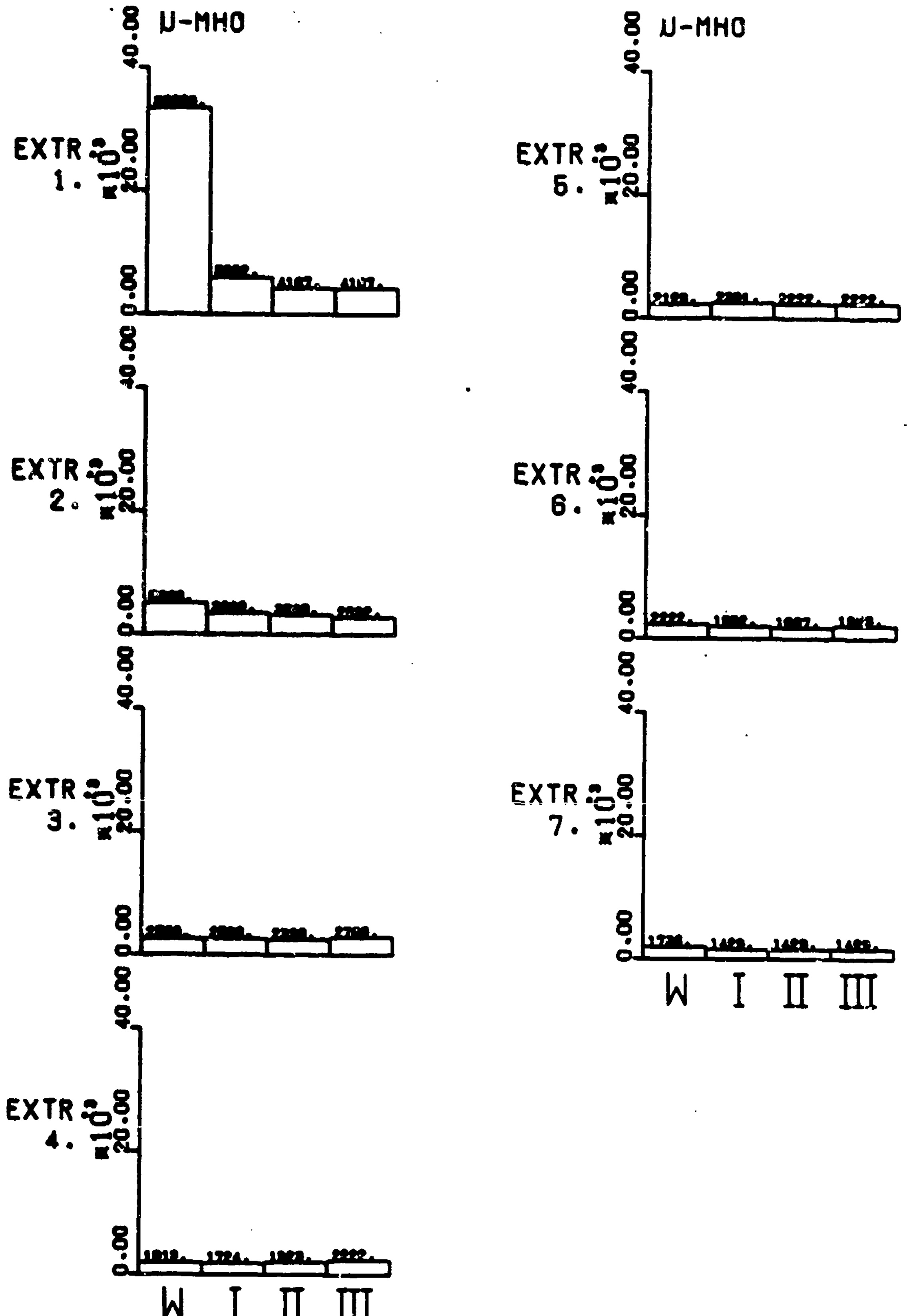


FIGURE 67. CONDUCTANCE OF EXTRACT FROM HYDROFLUORIC ACID WASTE ON DAVIDSON SOIL.

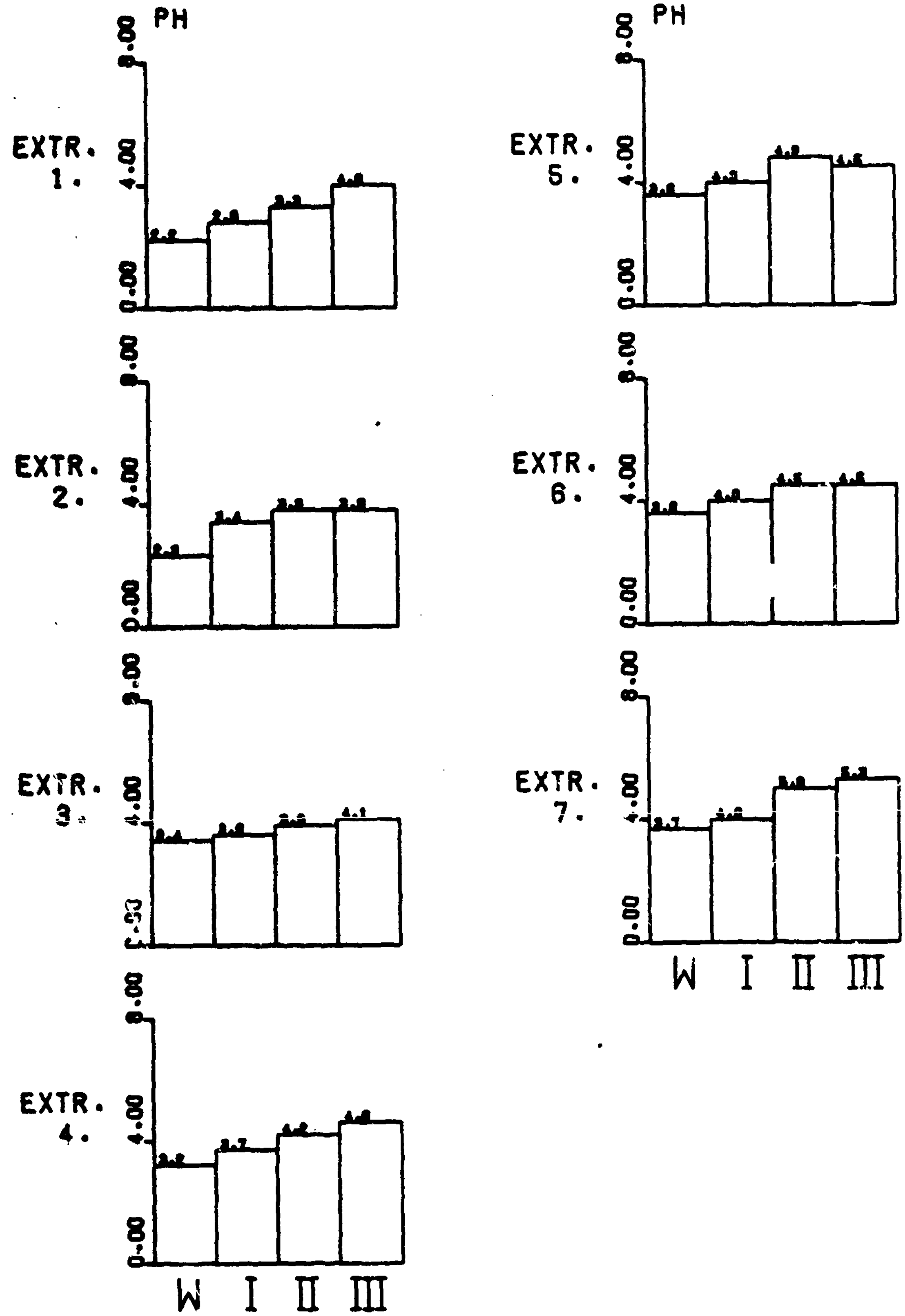


FIGURE 68. pH OF EXTRACT FROM HYDROFLUORIC ACID WASTE ON DAVIDSON SOIL.

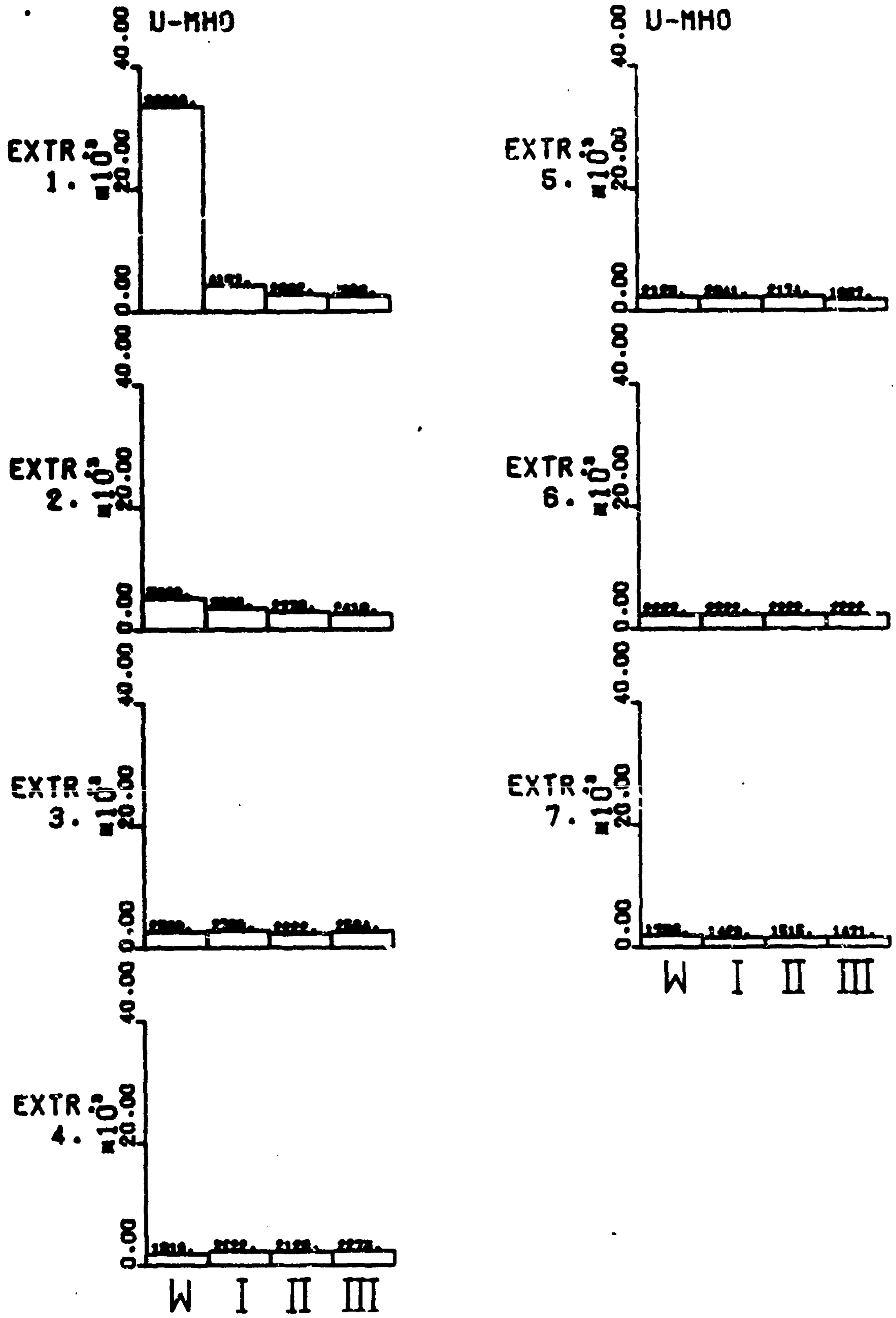


FIGURE 69. CONDUCTANCE OF EXTRACT FROM HYDROFLUORIC ACID WASTE ON NICHOLSON SOIL.

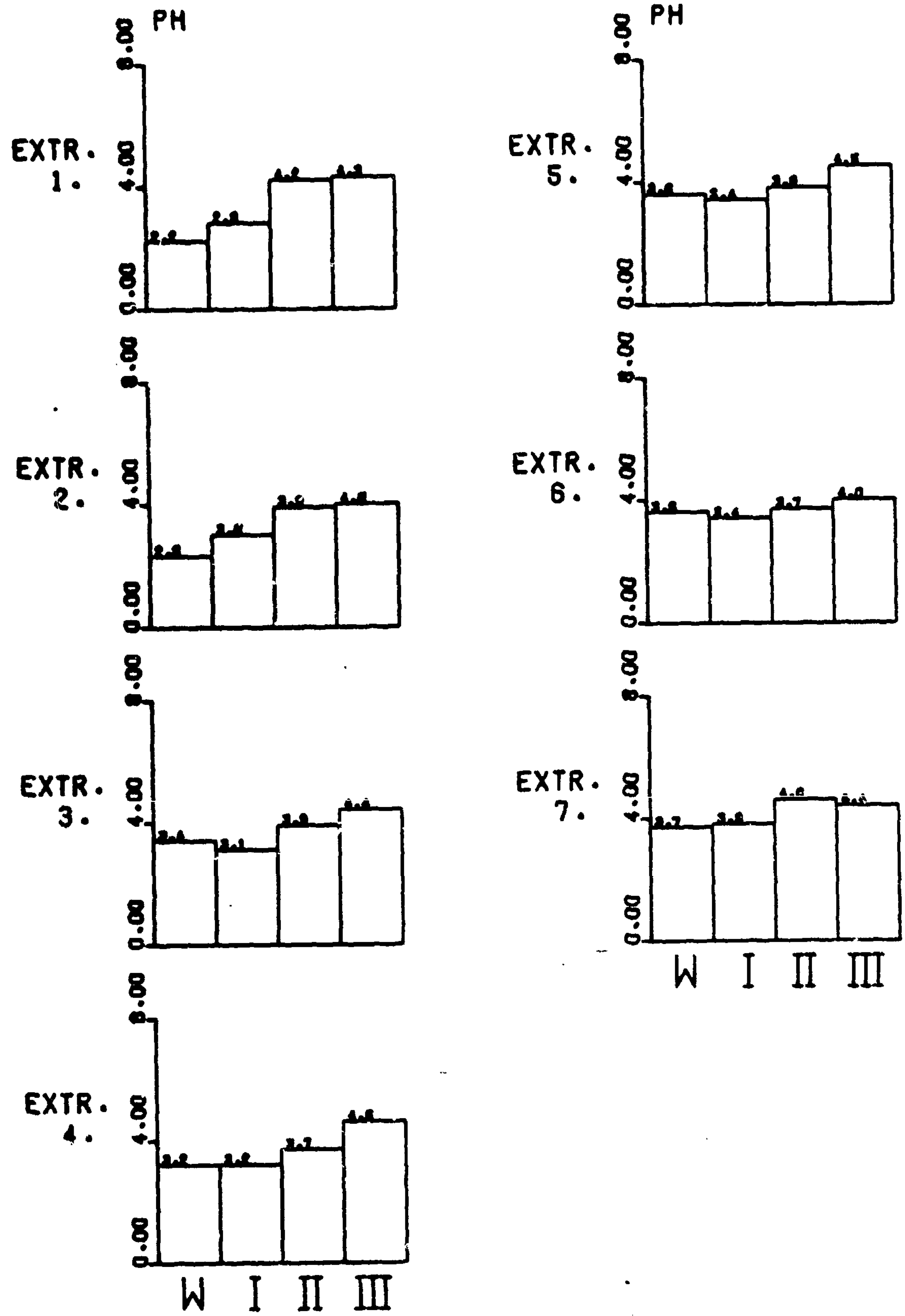


FIGURE 70. pH OF EXTRACT FROM HYDROFLUORIC ACID WASTE ON NICHOLSON SOIL.

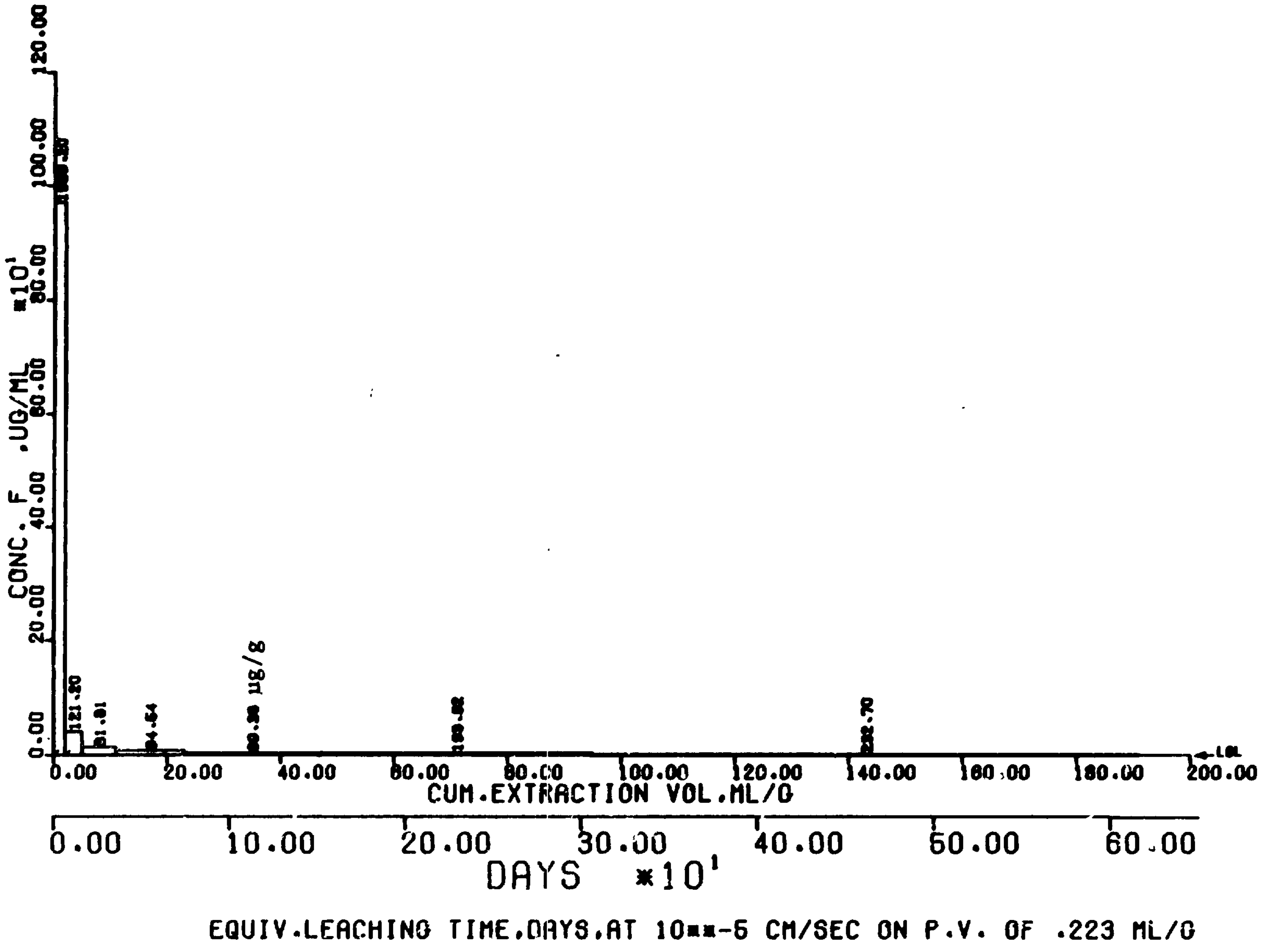


FIGURE 71. EXTRACTION OF FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE.

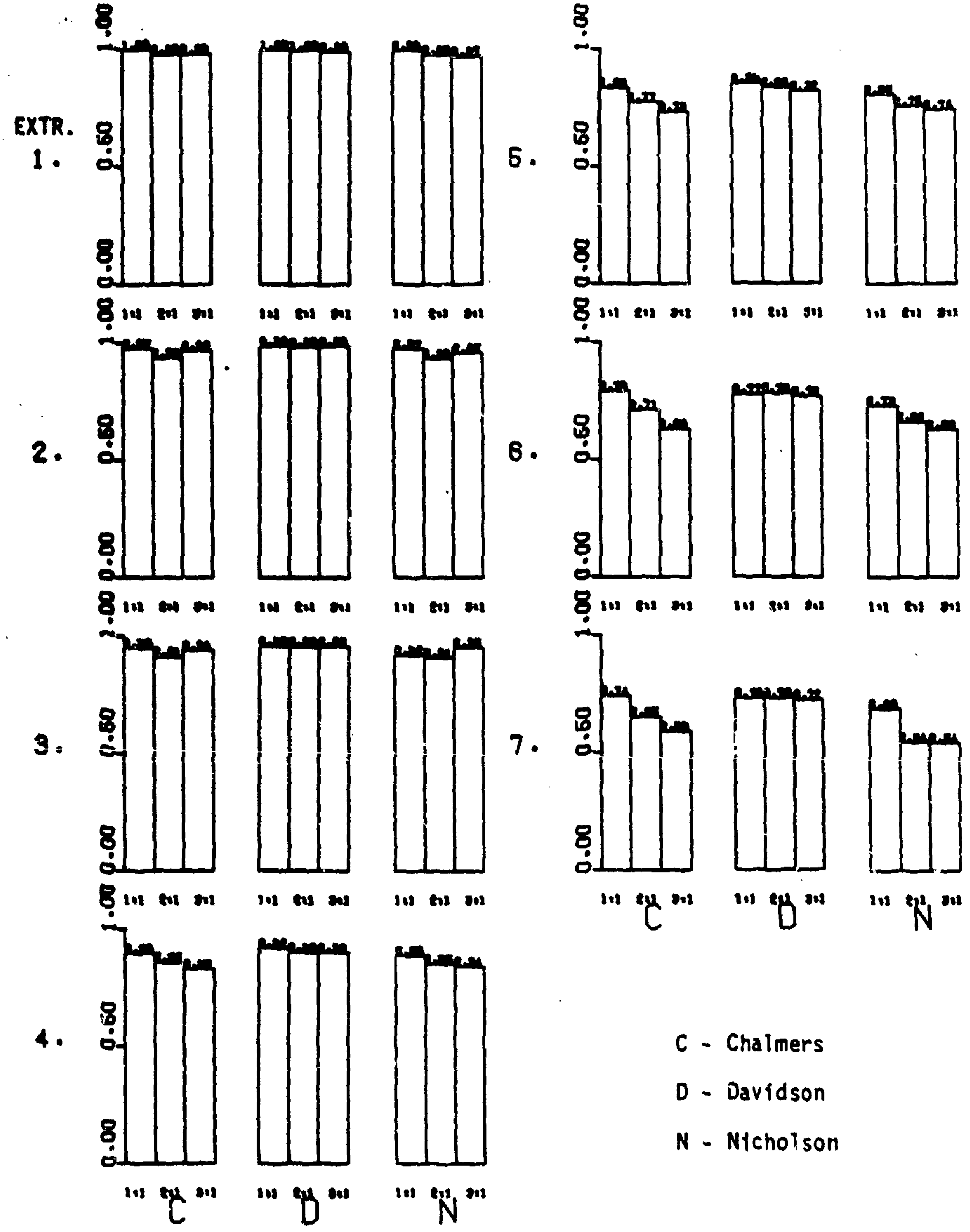


FIGURE 72. COMPARING FRACTION FLUORINE RETAINED BY SOILS FROM HYDROFLUORIC ACID PRODUCTION WASTE LEACHATE.

TABLE 39. FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	969.60	1939.20										
	I	4.65	9.29	1929.91	1939.20	1929.91	1.00	1.00	.00	294.87	89.81	207.70	89.72
	II	22.72	45.45	-36.16	9.29	-36.16	-3.89	-3.89	4.89	17.03	86.64	-.80	-38.50
	III	20.30	40.60	4.85	45.45	4.85	.11	.11	.89	20.07	87.15	.12	6.81
	I+II			946.88	969.60	946.88	.98	.98	.02	112.95	89.49	41.67	88.63
	I+II+III			632.87	646.40	632.87	.98	.98	.02	226.31	89.75	46.76	88.77
2	W	40.40	121.20										
	I	14.95	44.84	76.36	2060.40	2006.26	.63	.97	.37	62.30	89.09	44.74	88.72
	II	30.40	91.20	-46.36	54.14	-82.52	-1.83	-1.52	2.83	7.98	82.85	-.90	-42.14
	III	10.60	31.81	59.39	136.65	64.24	.65	.47	.35	27.40	87.92	2.02	63.65
	I+II			15.09	1030.20	961.87	.25	.93	.75	56.62	88.99	21.09	87.29
	I+II+III			29.82	686.80	662.66	.74	.96	.26	291.62	89.80	62.49	89.09
3	W	13.64	81.81										
	I	10.50	63.02	10.79	2142.21	2025.05	.23	.95	.77	44.98	88.73	32.13	88.22
	II	9.70	58.10	4.85	117.16	-77.67	.08	-.66	.92	12.59	85.46	-1.34	-53.17
	III	10.91	65.45	-7.27	194.83	56.96	-.12	.29	1.12	13.25	85.68	.87	41.04
	I+II			11.02	1071.10	973.69	.29	.91	.71	89.17	89.36	33.47	88.29
	I+II+III			5.45	714.07	668.11	.20	.94	.80	142.81	89.60	30.63	88.13
4	W	7.00	94.54										
	I	10.10	121.20	-26.66	2236.75	1998.39	-.28	.89	1.28	23.17	87.53	16.49	86.53
	II	10.50	126.05	-4.85	230.36	-82.52	-.04	-.35	1.04	5.77	80.17	-.65	-33.21
	III	29.48	244.82	-118.78	320.88	-61.81	-.94	-.19	1.74	3.86	71.88	-.25	-14.17
	I+II			-15.76	1118.37	957.93	-.33	.86	1.33	40.90	88.60	15.20	86.24
	I+II+III			-50.10	745.58	618.02	-1.59	.83	2.59	37.35	88.47	7.57	82.48
5	W	4.14	99.38										
	I	6.46	155.14	-55.75	2336.13	1942.63	-.56	.83	1.56	17.74	86.77	12.52	85.43
	II	8.89	213.31	-58.18	393.50	-140.69	-.38	-.36	1.38	3.14	72.32	-.66	-33.41
	III	10.30	247.25	-33.94	534.19	-95.75	-.16	-.18	1.16	2.89	70.91	-.39	-21.17
	I+II			-56.96	1168.06	900.97	-1.15	.77	2.15	23.64	87.58	8.45	83.25
	I+II+III			-49.29	778.71	560.73	-1.49	.73	2.49	36.39	88.43	6.90	81.75
6	W	4.84	193.92										
	I	2.93	140.59	53.33	2530.05	1995.96	.27	.79	.73	19.96	87.13	14.20	85.97
	II	4.14	198.77	-58.18	534.09	-198.87	-.41	-.37	1.41	3.07	71.98	-1.00	-45.01
	III	6.46	310.27	-111.50	732.96	-207.25	-.56	-.28	1.56	1.94	62.76	-.67	-33.74
	I+II			-2.42	1265.02	898.55	-.03	.71	1.03	25.34	87.7[illegible]	9.04	83.69
	I+II+III			-38.78	843.35	529.95	-.60	.63	1.60	20.62	88.00	[illegible].12	78.96
7	W	2.42	232.70										
	I	1.92	184.22	48.48	2762.75	2044.44	.21	.74	.79	15.49	86.31	11.[illegible]	84.85
	II	2.42	232.70	-48.48	718.31	-247.35	-.26	-.34	1.26	2.42	67.53	-1.06	-46.75
	III	2.02	193.92	38.78	965.66	-168.47	.17	-.17	.83	3.31	73.18	-.87	-40.98
	I+II			.00	1381.38	898.55	.00	.65	1.00	21.65	87.35	7.72	82.62
	I+II+III			12.93	920.92	542.88	.17	.59	.83	45.99	88.75	8.40	83.21

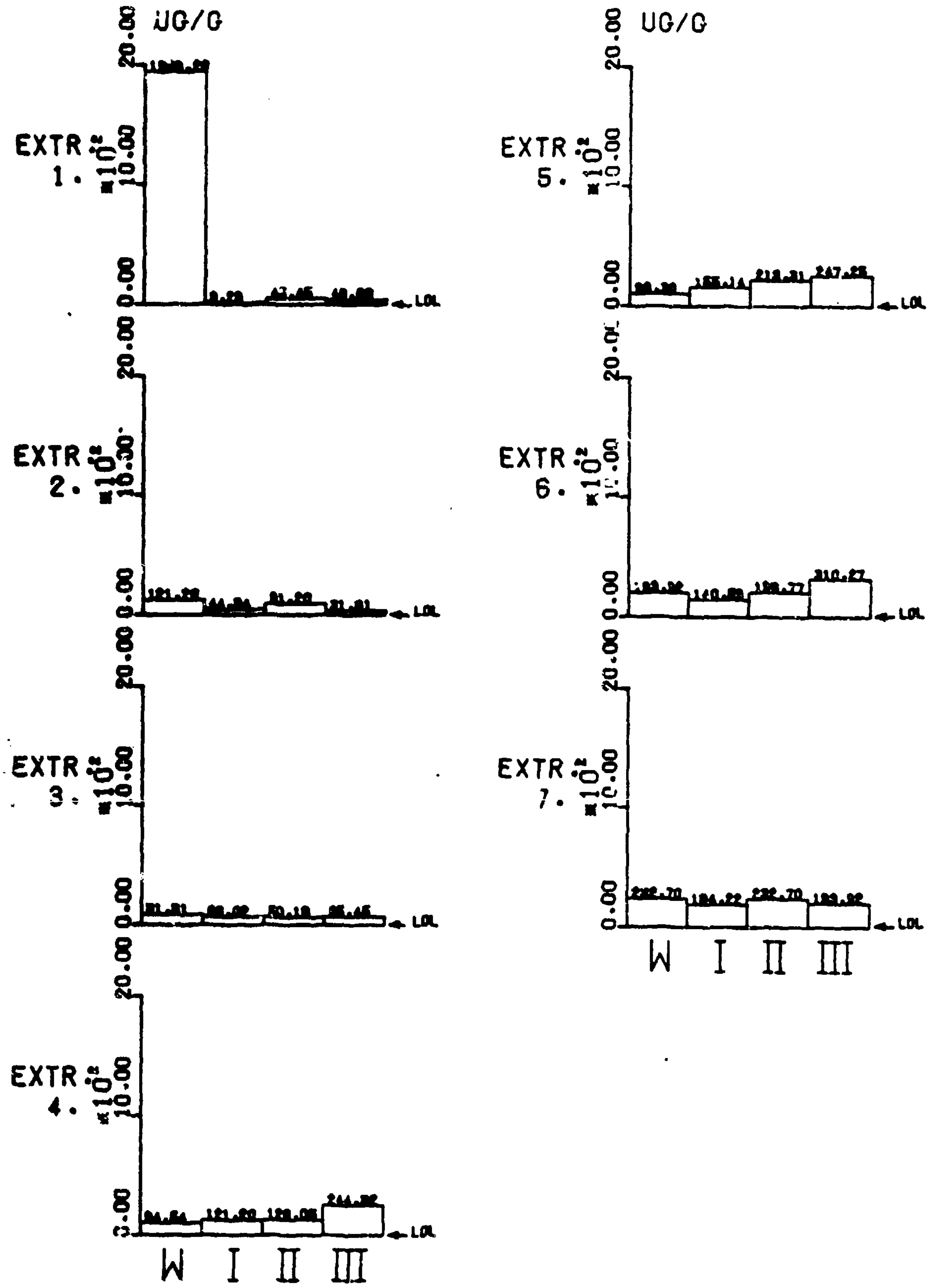


FIGURE 73. WEIGHT OF FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE ON CHALMERS SOIL.

TABLE 40. FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE ON DAVIDSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	969.60	1939.20										
	I	2.32	4.65	1934.55	1939.20	1934.55	1.00	1.00	.00	465.47	89.88	416.39	89.86
	II	4.85	9.70	-5.05	4.65	-5.05	-1.09	-1.09	2.09	22.99	87.51	-.52	-27.51
	III	10.30	20.60	-10.91	9.70	-10.91	-1.12	-1.12	2.13	10.54	84.58	-.53	-27.90
	I+II			964.75	969.60	964.75	1.00	1.00	.01	293.06	89.80	199.00	89.71
	I+II+III			639.53	646.40	639.53	.99	.99	.01	192.71	89.70	93.12	89.38
2	W	40.40	121.20										
	I	9.70	29.09	92.11	2060.40	2026.67	.76	.98	.24	77.51	89.26	69.67	89.18
	II	10.20	30.60	-1.51	33.73	-6.56	-.05	-.19	1.05	7.24	82.13	-.21	-12.11
	III	5.05	15.15	15.45	40.30	4.55	.50	.11	.50	15.35	86.27	.30	16.70
	I+II			45.30	1030.20	1010.05	.75	.98	.25	95.81	89.40	65.01	89.13
	I+II+III			35.35	686.80	674.88	.88	.98	.13	269.09	89.79	133.64	89.57
3	W	13.64	81.81										
	I	10.40	62.42	19.39	2142.21	2046.06	.24	.96	.76	36.43	88.43	32.78	88.25
	II	10.10	60.60	1.82	76.15	-4.75	.03	-.05	.97	3.68	74.81	-.08	-4.48
	III	10.50	63.02	-2.42	100.90	2.12	-.04	.02	1.04	3.55	74.68	.03	1.93
	I+II			10.60	1071.10	1020.66	.26	.95	.74	48.73	88.82	33.68	88.30
	I+II+III			6.26	714.07	681.14	.23	.95	.77	64.98	89.12	32.42	88.23
4	W	7.88	94.54										
	I	7.47	89.69	4.85	2236.75	2050.91	.05	.92	.95	25.41	87.75	22.87	87.50
	II	10.20	122.41	-32.72	185.84	-37.47	-.36	-.20	1.36	1.56	57.28	-.31	-17.02
	III	10.71	128.47	-6.06	227.31	-3.94	-.05	-.02	1.05	1.74	60.17	-.03	-1.76
	I+II			-13.94	1118.37	1006.72	-.29	.90	1.29	23.90	87.60	16.45	86.52
	I+II+III			-11.31	745.58	669.83	-.36	.90	1.36	31.61	88.19	15.64	86.34
5	W	4.14	99.38										
	I	6.87	164.83	-65.45	2336.13	1985.46	-.66	.85	1.66	13.43	85.74	12.05	85.25
	II	7.07	169.68	-4.85	350.67	-42.32	-.03	-.12	1.03	1.09	47.58	-.25	-14.00
	III	8.48	203.62	-33.94	392.99	-37.87	-.20	-.10	1.20	.93	43.04	-.19	-10.54
	I+II			-35.15	1168.06	971.57	-.71	.83	1.71	16.83	86.60	11.45	85.01
	I+II+III			-34.74	778.71	635.09	-1.05	.82	2.05	19.43	87.05	9.36	83.90
6	W	4.04	193.92										
	I	4.65	223.01	-29.09	2530.05	1956.37	-.15	.77	1.15	9.80	84.17	8.77	83.50
	II	3.53	169.68	53.33	573.68	11.01	.24	.02	.76	1.41	54.63	.06	3.71
	III	3.53	169.68	.00	562.67	-37.87	.00	-.07	1.00	1.12	48.25	-.22	-12.58
	I+II			12.12	1265.02	983.69	.13	.78	.87	16.97	86.63	11.59	85.07
	I+II+III			8.08	843.35	643.17	.13	.76	.87	23.46	87.56	11.37	84.97
7	W	2.42	232.70										
	I	1.82	174.53	58.18	2762.75	2014.55	.25	.73	.75	12.85	85.55	11.54	85.05
	II	1.92	184.22	-9.70	748.21	1.31	-.06	.00	1.06	1.24	51.22	.01	.41
	III	1.72	164.83	19.39	746.90	-18.48	.11	-.02	.89	1.27	51.81	-.11	-6.40
	I+II			24.24	1381.38	1007.93	.21	.73	.79	15.89	86.40	10.94	84.78
	I+II+III			22.62	920.92	665.79	.29	.72	.71	24.57	87.67	12.12	85.28

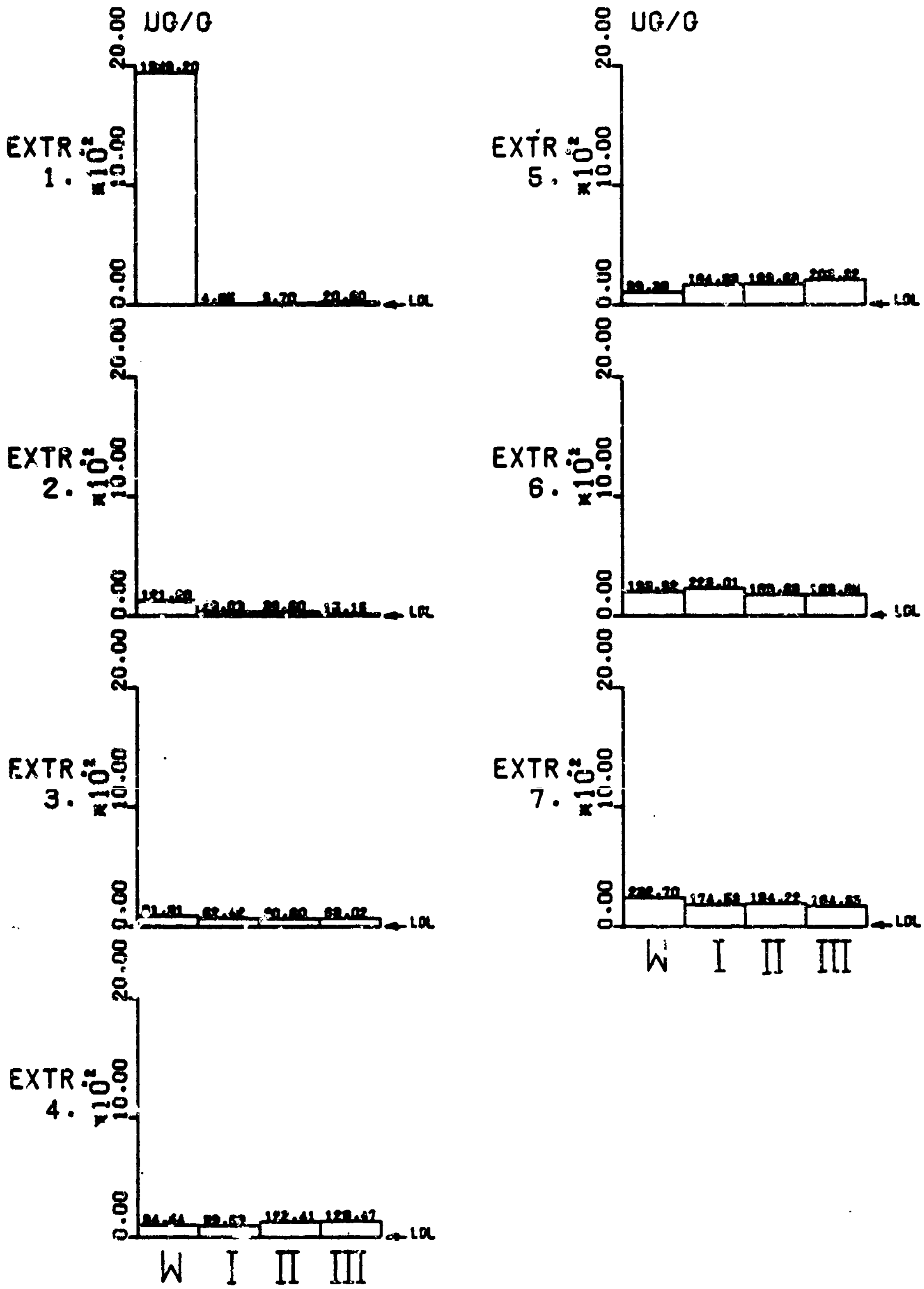


FIGURE 74. WEIGHT OF FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE ON DAVIDSON SOIL.

TABLE 41. FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE ON NICHOLSON SOIL.

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	969.60	1939.20										
	I	5.86	11.72	1927.48	1939.20	1927.48	.99	.99	.01	297.67	89.81	164.52	89.65
	II	23.84	47.67	-35.96	11.72	-35.96	-3.07	-3.07	4.07	31.97	88.21	-.75	-37.02
	III	30.40	60.80	-13.13	47.67	-13.13	-.28	-.28	1.28	25.44	87.75	-.22	-12.19
	I+II			945.76	969.60	945.76	.98	.98	.02	170.57	89.66	39.68	88.56
	I+II+III			626.13	646.40	626.13	.97	.97	.03	261.81	89.78	30.89	88.15
2	W	40.40	121.20										
	I	14.65	43.94	77.27	2060.40	2004.75	.64	.97	.36	81.14	89.29	45.63	88.74
	II	30.91	92.72	-48.78	55.65	-84.74	-1.11	-1.52	2.11	15.91	86.40	-.91	-42.43
	III	10.91	32.72	59.99	140.39	46.86	.65	.33	.35	49.10	88.83	1.43	55.07
	I+II			14.24	1030.20	960.01	.24	.93	.76	88.01	89.35	20.71	87.24
	I+II+III			29.49	686.80	655.62	.73	.95	.27	409.15	89.88	60.10	89.05
3	W	13.64	81.81										
	I	20.81	124.84	-43.03	2142.21	1961.72	-.53	.92	1.53	28.21	87.97	15.71	86.36
	II	10.10	60.60	64.24	180.49	-20.50	.51	-.11	.49	25.40	87.75	-.34	-18.69
	III	2.73	16.36	44.24	200.99	91.10	.73	.45	.27	100.91	89.43	5.57	79.82
	I+II			19.60	1071.10	970.61	.26	.91	.74	135.00	89.58	32.03	88.21
	I+II+III			21.62	714.07	677.44	.80	.95	.20	982.30	89.94	124.21	89.54
4	W	7.88	94.54										
	I	6.06	72.72	21.82	2236.75	1983.54	.23	.89	.77	48.73	88.82	27.23	87.90
	II	10.91	130.90	-58.18	253.21	-78.68	-.80	-.31	1.80	11.32	84.95	-.60	-31.01
	III	20.60	247.25	-116.35	331.89	-25.25	-.89	-.08	1.89	6.21	80.85	-.10	-5.83
	I+II			-18.18	1118.37	952.43	-.38	.85	1.38	62.22	89.08	14.55	86.07
	I+II+III			-50.90	715.58	626.54	-1.62	.84	2.62	64.39	89.11	7.60	82.51
5	W	4.14	99.32										
	I	8.40	203.62	-104.23	2336.13	1879.31	-1.05	.80	2.05	16.89	86.61	9.23	83.82
	II	10.20	244.82	-41.21	456.82	-119.89	-.20	-.26	1.20	5.38	80.35	-.49	-26.09
	III	10.50	252.10	-7.27	576.71	-32.52	-.03	-.06	1.03	6.06	80.63	-.13	-7.35
	I+II			-72.72	1168.06	879.71	-1.46	.75	2.46	32.67	88.25	7.1[illegible]	82.08
	I+II+III			-50.90	778.71	575.63	-1.54	.74	2.54	62.54	89.08	6.85	81.69
6	W	4.04	193.92										
	I	4.85	232.70	-38.78	2530.05	1840.52	-.20	.73	1.20	14.61	86.09	7.91	82.79
	II	5.96	286.03	-53.33	689.53	-173.21	-.23	-.25	1.23	4.85	78.35	-.61	-31.20
	III	7.07	339.36	-53.33	862.74	-85.85	-.19	-.10	1.19	4.34	77.04	-.25	-14.20
	I+II			-46.06	1265.02	833.65	-.47	.66	1.[illegible]	2[illegible].64	87.93	5.83	[illegible].27
	I+II+III			-40.48	843.35	527.[illegible]	-.75	.63	1.75	40.03	88.76	4.66	7[illegible].[illegible]9
7	W	2.42	232.70										
	I	1.82	174.53	58.18	2762.75	1898.70	.25	.69	.75	19.82	87.1[illegible]	10.88	8[illegible]
	II	4.14	397.34	-223.01	864.06	-396.22	-1.28	-.46	2.28	2.93	[illegible].14	1.00	-4[illegible].91
	III	3.33	319.97	77.57	1[illegible]60.[illegible]8	-8.28	.20	-.01	.80	4.85	[illegible]3.35	-.03	-[illegible].48
	I+II			-82.42	1381.38	751.24	-.71	.54	1.71	19.48	87.06	3.78	[illegible].18
	I+II+III			-29.09	920.9[illegible]	498.[illegible]6	-.37	[illegible]	[illegible]	48.[illegible]	[illegible]	4.67	7[illegible].91

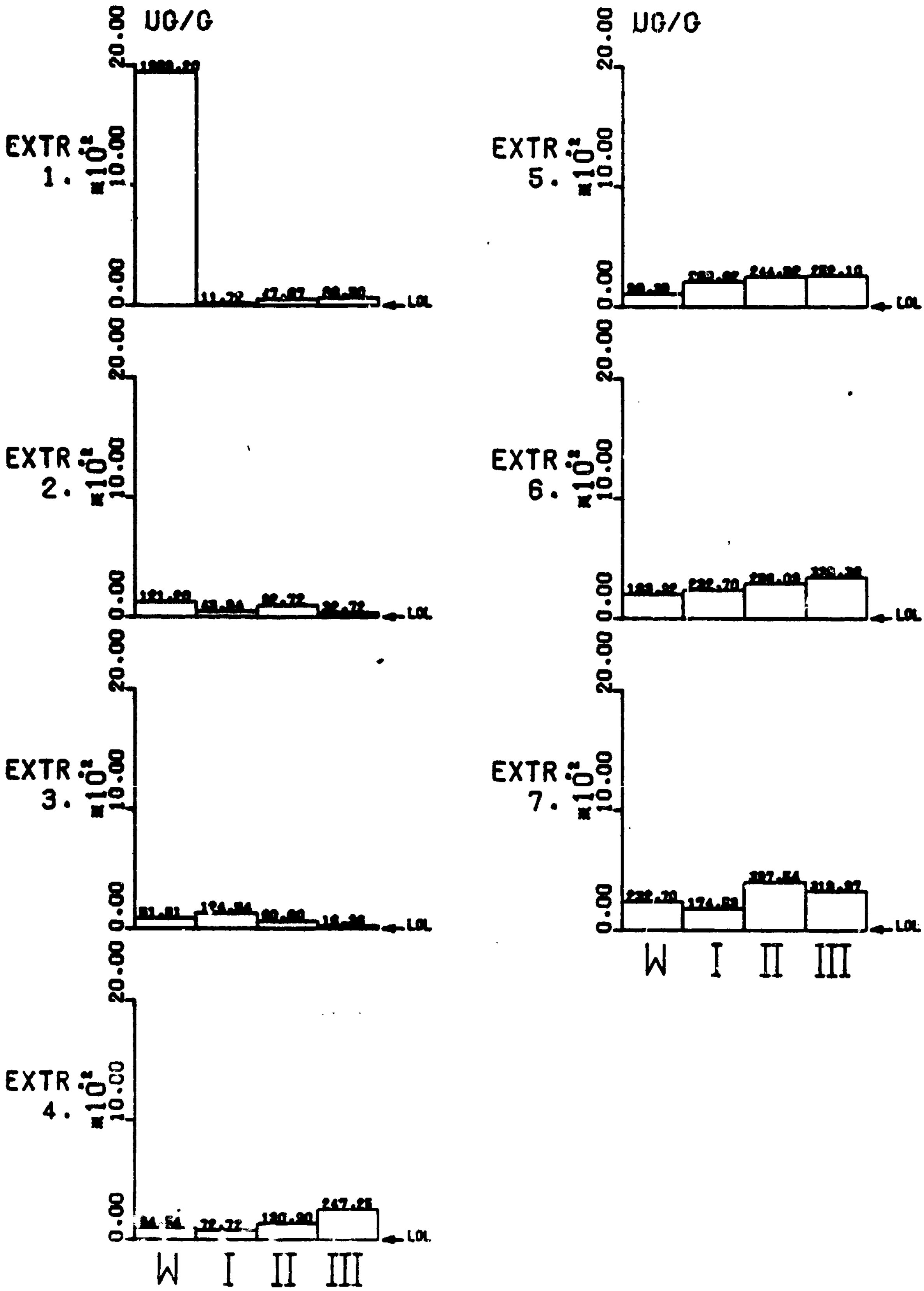


FIGURE 75. WEIGHT OF FLUORINE FROM HYDROFLUORIC ACID PRODUCTION WASTE ON NICHOLSON SOIL.

WHITE PHOSPHORUS PRODUCTION WASTE

Gases from the electric furnace production of phosphorus are collected in a water scrubber and the resultant liquor is treated with lime. Table 42 shows that water extracts of this waste were highly basic. Figures 76 to 81 indicate that all three soils were quite effective in reducing the content of soluble materials in this leachate until the sixth extraction, when some flushed off the soils. The ability of these soils to attenuate the pH was exhausted by five extractions totaling 47 milliliters/gram.

TABLE 42. LEACHABILITY OF WHITE PHOSPHORUS PRODUCTION WASTE

Element	Initial Conc. (μg/ml)	When Concentration Levels Off				Total Weight Extracted (μg/g waste)	Percentage Extracted
		Conc. (μg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days		
F	2.9	1.9	7	190	620	358	0.16
P	10.5	0.6	4	23	75	45.5	0.32

Measurement	Initial	Final	Estim.Tot.Extr. (μ equiv/g)
Conduct. (μ mho)	9,302.	313.	2,207.
pH	12.3	11.0	--

Fluorine

Fluoride ions were present in the leachate from this waste in very low concentrations (3.5 to 1.6 μg/ml). Figure 82 and Table 42 indicate that the fluoride concentration soon became relatively constant and that in seven extractions a total of 358 μg/g, or 0.16 percent was extracted from that originally in the waste. Tables 43 to 45 and Figures 84 to 86 show that an average of 23 percent of the fluoride penetrated the soils in the first extract and that increasing amounts of fluoride were found in the effluents from succeeding challenges. Figure 83 displays graphically the importance of soil-to-waste ratio in retaining fluoride and that Nicholson soil soon began to yield fluoride from its own fluoride-containing components.

Phosphorus

Tables 42, 46 to 48 and Figure 87 show that the concentration of phosphorus in the first extract was 10.5 μg/ml and dropped to the region of the detection limit by the fourth extract, yielding a total of 45 μg/g, which is 0.32 percent of the phosphorus present in the waste. Figures 88 to 91 show that 39 percent of the phosphorus in the first extract penetrated the third layer of Davidson and Nicholson soils and 84 percent penetrated the Chalmers soil. By the third extraction all the soils were giving up phosphorus, with Davidson retaining a net of 27 percent of the cumulative challenge.

Summary

White phosphorus production waste yielded a solution of high pH although the concentration of fluorides and phosphorus-containing compounds were very low. Only a few tenths of a percent of the available fluorine and phosphorus were removed in the seven extractions, but the waste appeared to be a long-term source of fluoride ion. After continued exposure to the strongly basic leachate the soils lost their ability to reduce the pH and they also started to release previously-retained fluoride and phosphorus.

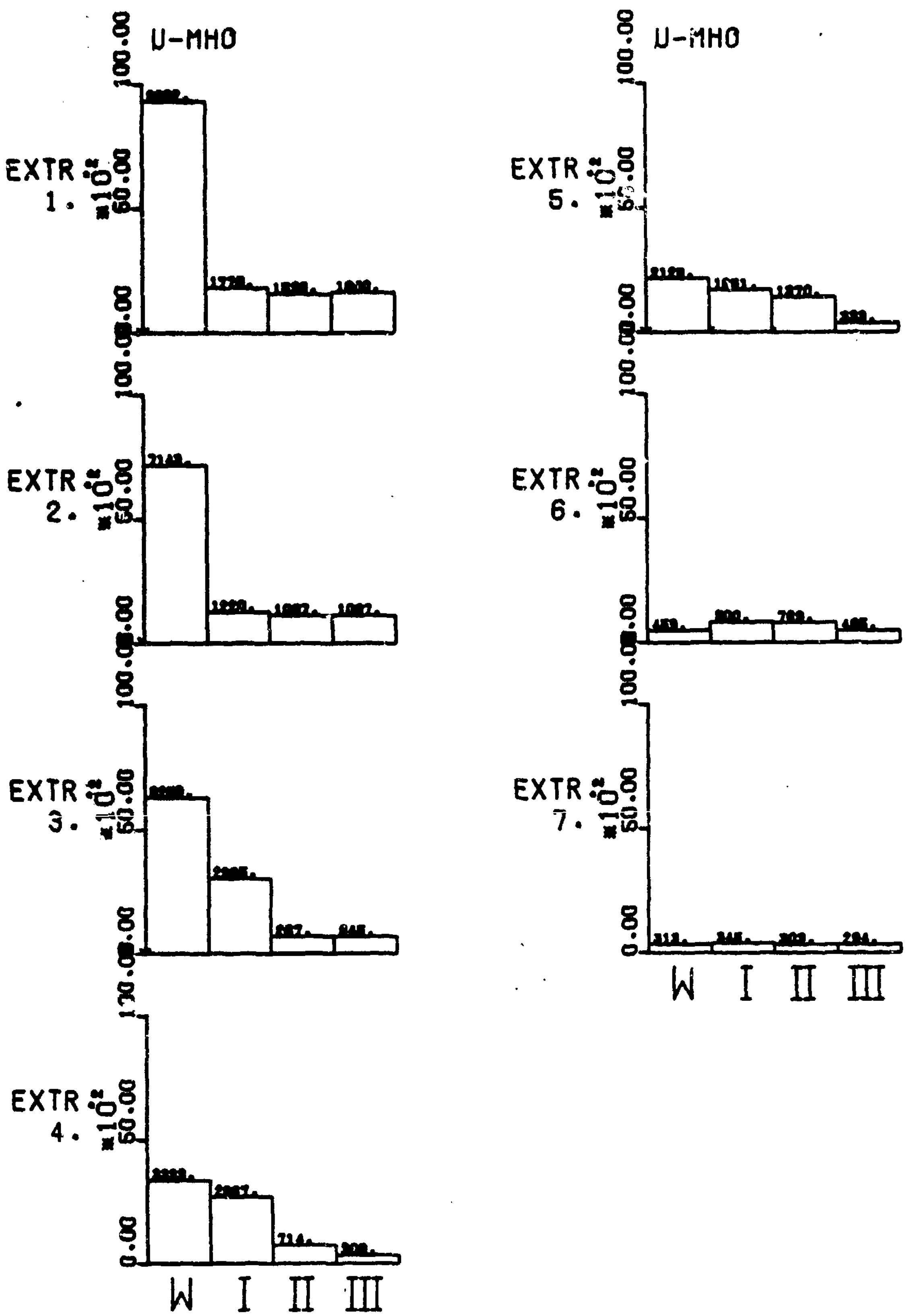


FIGURE 76. CONDUCTANCE OF EXTRACT FROM WHITE PHOSPHORUS PRODUCTION WASTE ON CHALMERS SOIL.

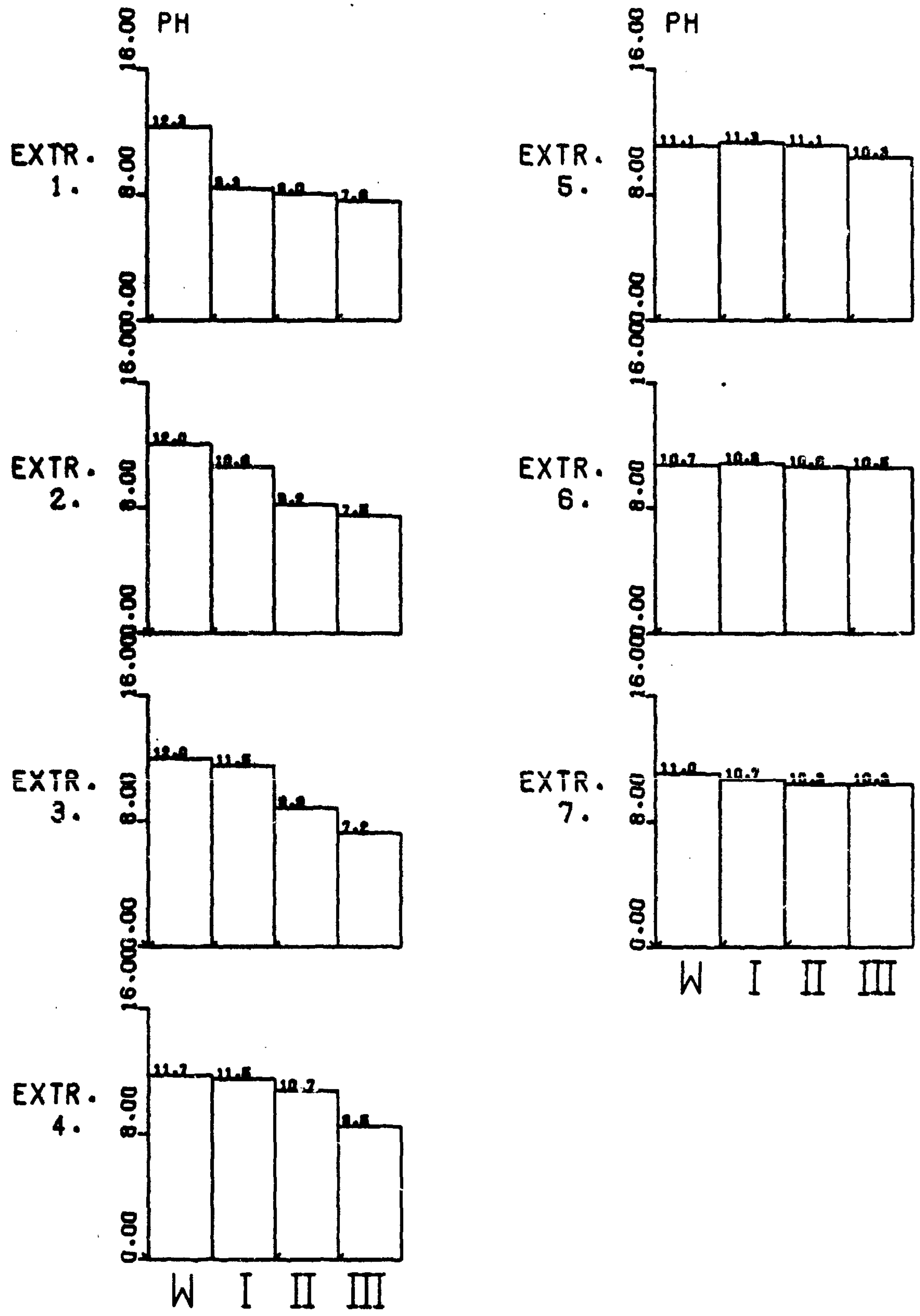


FIGURE 77. pH OF EXTRACT FROM WHITE PHOSPHORUS PRODUCTION WASTE ON CHALMERS SOIL.

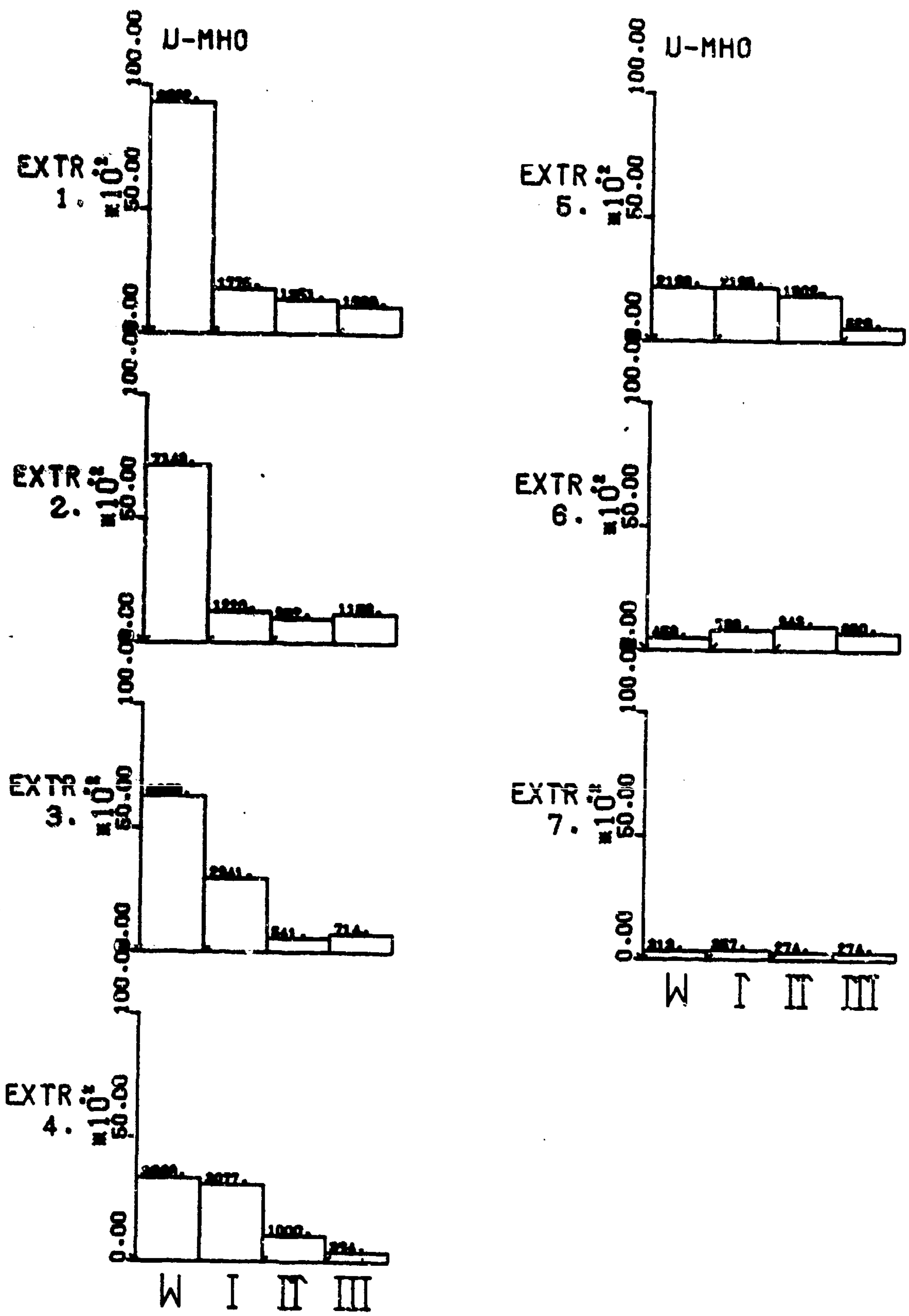


FIGURE 78. CONDUCTANCE OF EXTRACT FROM WHITE PHOSPHORUS PRODUCTION WASTE ON DAVIDSON SOIL.

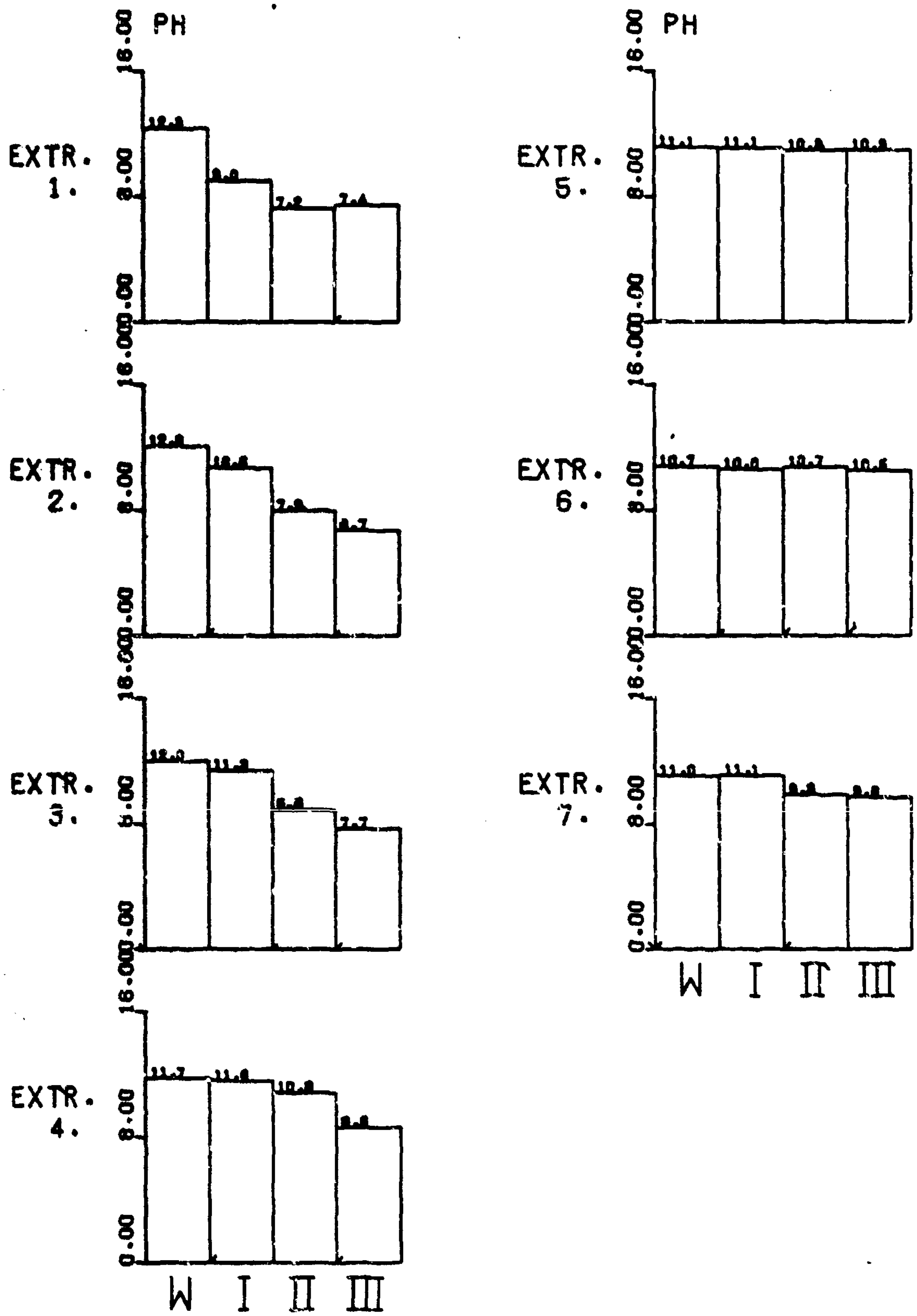


FIGURE 79. pH OF EXTRACT FROM WHITE PHOSPHORUS PRODUCTION WASTE ON DAVIDSON SOIL.

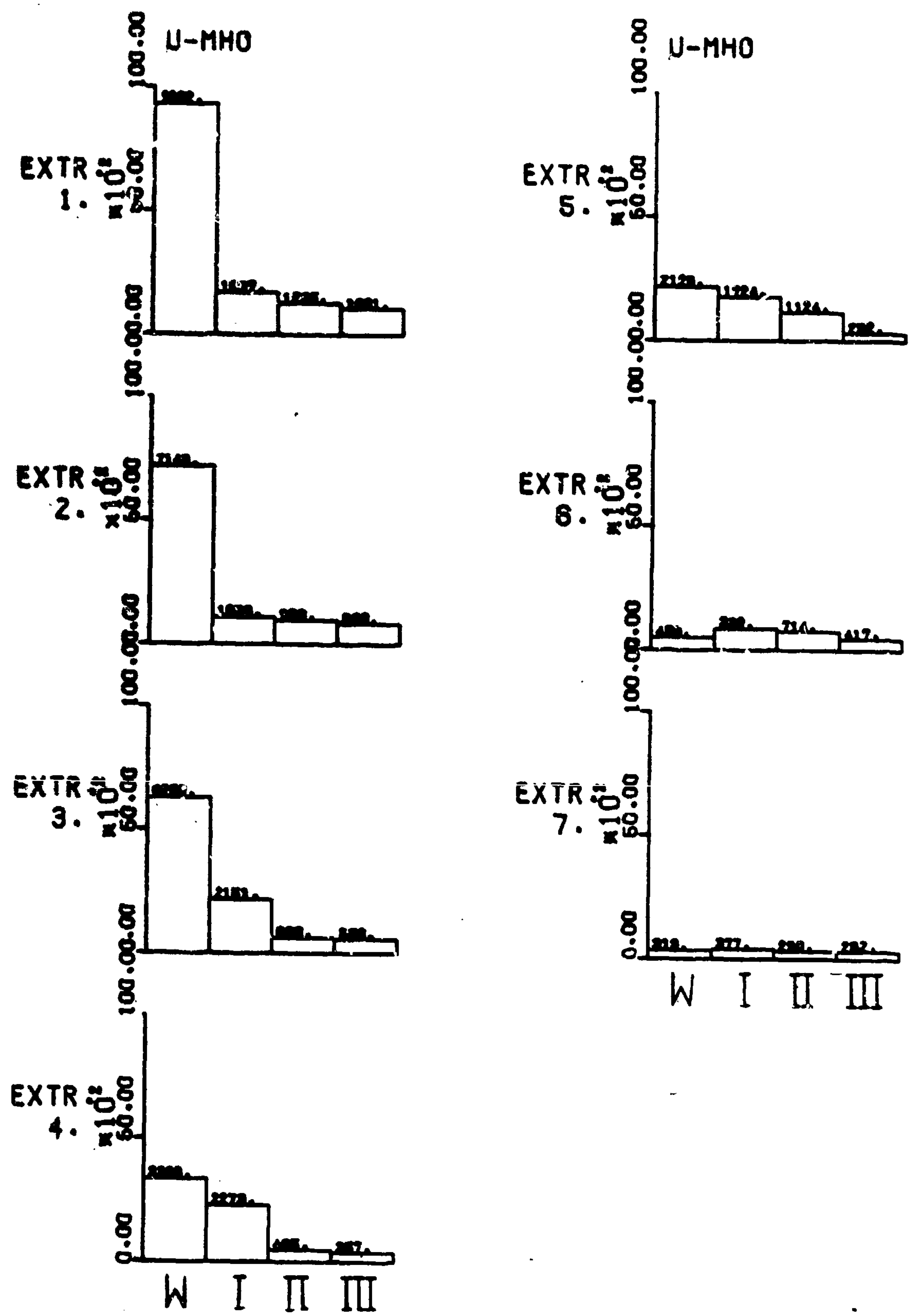


FIGURE 80. CONDUCTANCE OF EXTRACT FROM WHITE PHOSPHORUS PRODUCTION WASTE ON NICHOLSON SOIL.

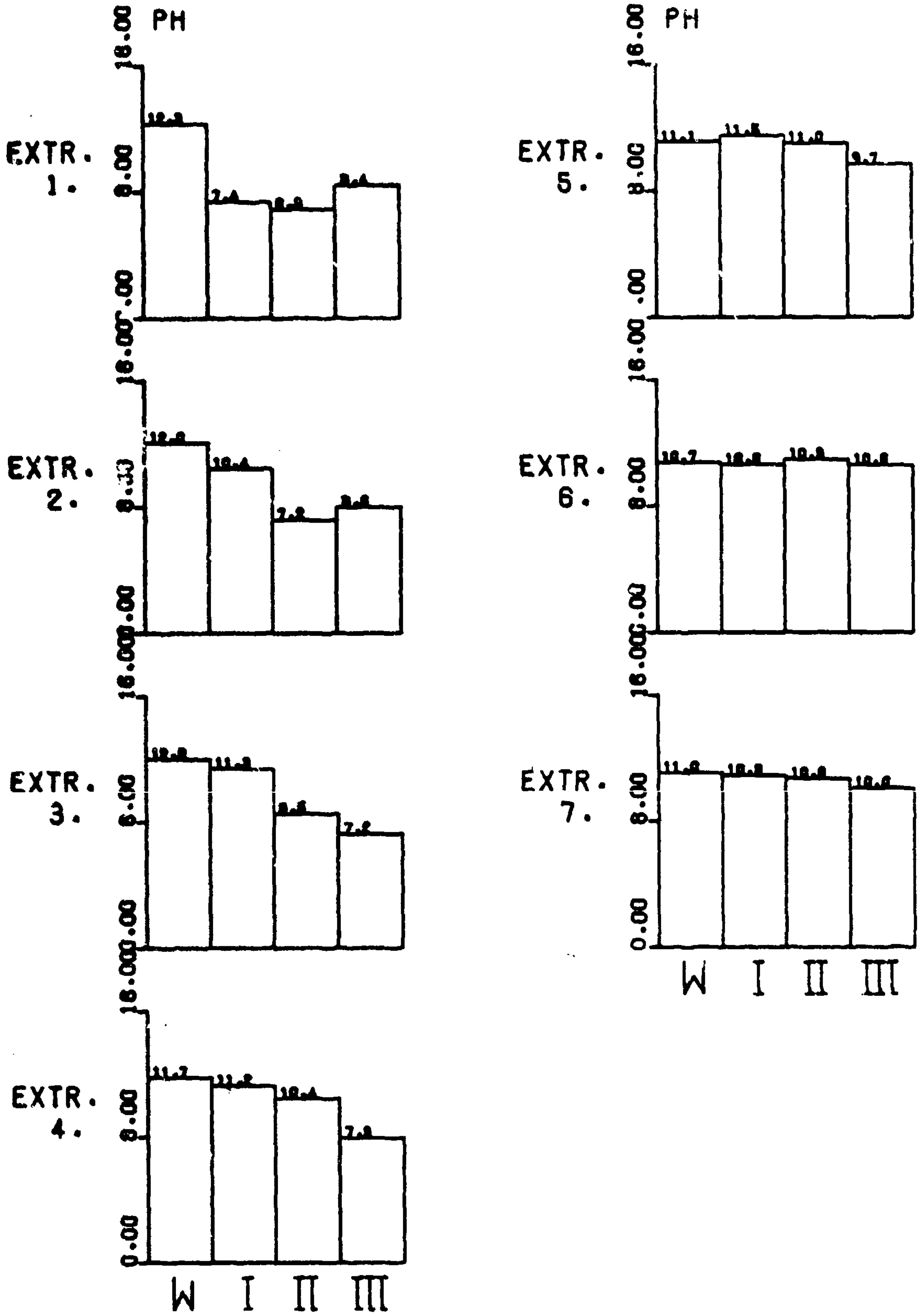


FIGURE 81. pH OF EXTRACT FROM WHITE PHOSPHORUS PRODUCTION WASTE ON NICHOLSON SOIL.

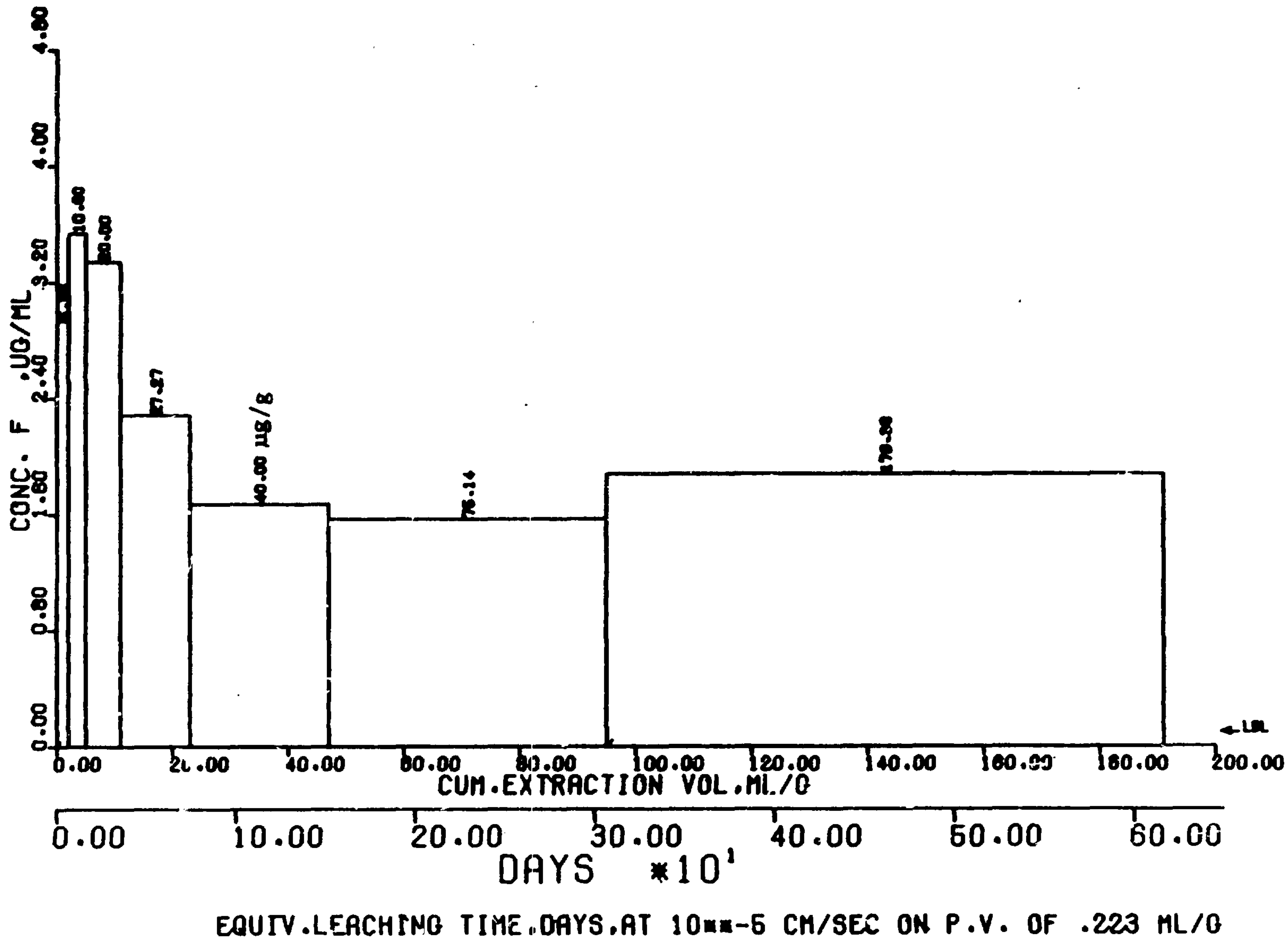


FIGURE 82. EXTRACTION OF FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE.

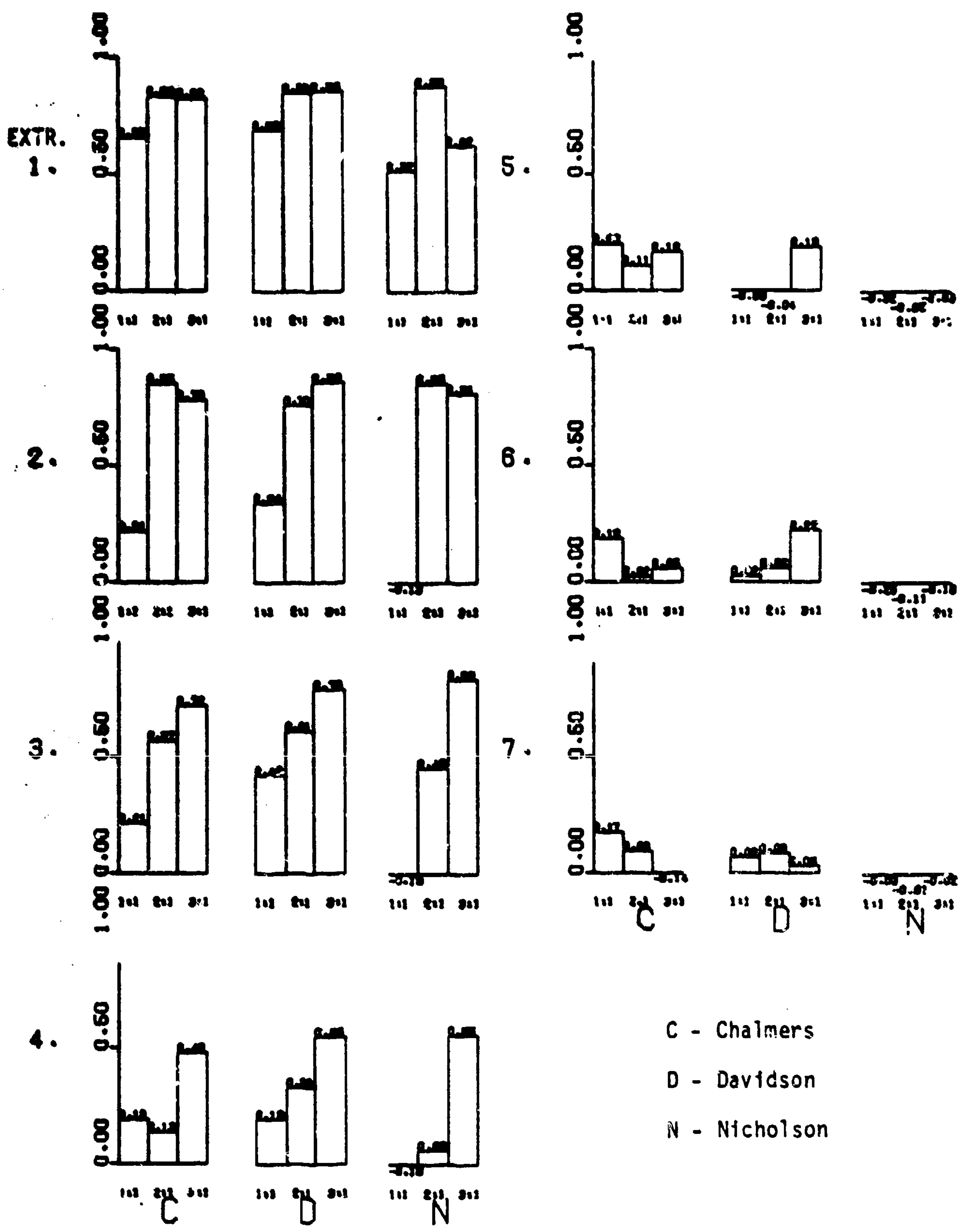


FIGURE 83. COMPARING FRACTION FLUORINE RETAINED BY SOILS FROM WHITE PHOSPHORUS PRODUCTION WASTE LEACHATE.

TABLE 43. FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	2.93	5.86										
	I	1.01	2.02	3.84	5.86	3.84	.66	.66	.34	402.89	89.86	1.90	62.24
	II	.49	.98	1.04	2.02	1.04	.52	.52	.49	827.85	89.93	1.06	46.72
	III	.52	1.03	-.05	.98	-.05	-.05	-.05	1.05	786.21	89.93	-.05	-2.81
	I+II			2.44	2.93	2.44	.83	.83	.17	3312.11	89.98	4.98	78.64
	I+II+III			1.61	1.95	1.61	.82	.82	.18	7080.98	89.99	4.69	77.95
2	W	3.53	10.60										
	I	3.64	10.91	-.30	16.46	3.54	-.03	.21	1.03	74.58	89.23	.32	17.96
	II	.50	1.50	9.41	12.93	10.45	.86	.81	.14	547.02	89.90	6.97	81.83
	III	.87	2.62	-1.12	2.49	-1.17	-.75	-.47	1.75	308.60	89.81	-.45	-24.09
	I+II			4.55	8.23	6.99	.86	.85	.14	2169.54	89.97	9.32	83.88
	I+II+III			2.64	5.49	4.27	.75	.78	.25	2786.32	89.98	4.89	78.44
3	W	3.33	20.00										
	I	2.63	15.76	4.24	36.46	7.78	.21	.21	.79	51.90	88.90	.49	26.27
	II	2.22	13.33	2.42	28.68	12.67	.15	.45	.85	61.72	89.07	.97	44.00
	III	1.11	6.67	6.67	15.81	5.49	.50	.35	.50	122.34	89.53	.82	39.50
	I+II			3.33	18.23	10.32	.33	.57	.67	244.57	89.77	1.55	57.15
	I+II+III			4.44	12.15	8.71	.67	.72	.33	1097.53	89.95	3.92	75.70
4	W	2.27	27.27										
	I	1.92	23.03	4.24	63.73	12.02	.16	.19	.84	35.70	88.40	.52	27.56
	II	3.28	39.39	-16.36	51.71	-3.49	-.71	-.07	1.71	20.48	87.20	-.09	-5.06
	III	1.92	23.03	16.36	55.20	21.86	.42	.40	.58	36.12	88.41	.95	43.50
	I+II			-6.06	31.87	4.26	-.44	.13	1.44	82.47	89.31	.22	12.22
	I+II+III			1.41	21.24	10.13	.16	.48	.84	317.89	89.82	1.32	52.84
5	W	1.67	40.00										
	I	1.31	31.51	8.48	103.73	20.50	.21	.20	.79	26.36	87.83	.65	33.05
	II	1.57	37.57	-6.06	83.22	-9.55	-.19	-.11	1.19	21.30	87.31	-.25	-14.26
	III	2.22	53.33	-15.76	92.77	6.10	-.42	.07	1.42	15.30	86.26	.11	6.53
	I+II			1.21	51.86	5.40	.06	.11	.94	86.53	89.34	.29	16.25
	I+II+III			-4.44	34.58	5.68	-.33	.16	1.33	137.02	89.58	.32	17.73
6	W	1.57	75.14										
	I	1.31	63.02	12.12	178.87	32.62	.16	.18	.84	13.37	85.72	.52	27.37
	II	1.72	82.42	-19.39	146.25	-28.94	-.31	-.20	1.31	9.48	83.98	-.35	-19.35
	III	1.72	82.42	.00	175.19	6.10	.00	.03	1.00	9.90	84.23	.07	4.23
	I+II			-3.64	89.44	1.84	-.10	.02	1.10	39.36	88.54	.04	2.56
	I+II+III			-2.42	59.62	3.26	-.10	.05	1.10	88.57	89.35	.12	6.77
7	W	1.87	179.38										
	I	1.57	150.29	29.09	358.25	61.71	.16	.17	.84	5.80	88.22	.41	22.32
	II	1.57	150.29	.00	296.54	-20.94	.00	-.10	1.00	5.20	79.11	-.19	-10.90
	III	2.47	237.55	-87.26	325.48	-81.16	-.58	-.25	1.58	3.07	71.95	-.34	-18.86
	I+II			14.54	179.12	16.38	.16	.09	.84	21.78	87.37	.22	12.30
	I+II+III			-19.39	119.42	-16.13	-.32	-.14	1.32	30.48	88.12	-.20	-11.51

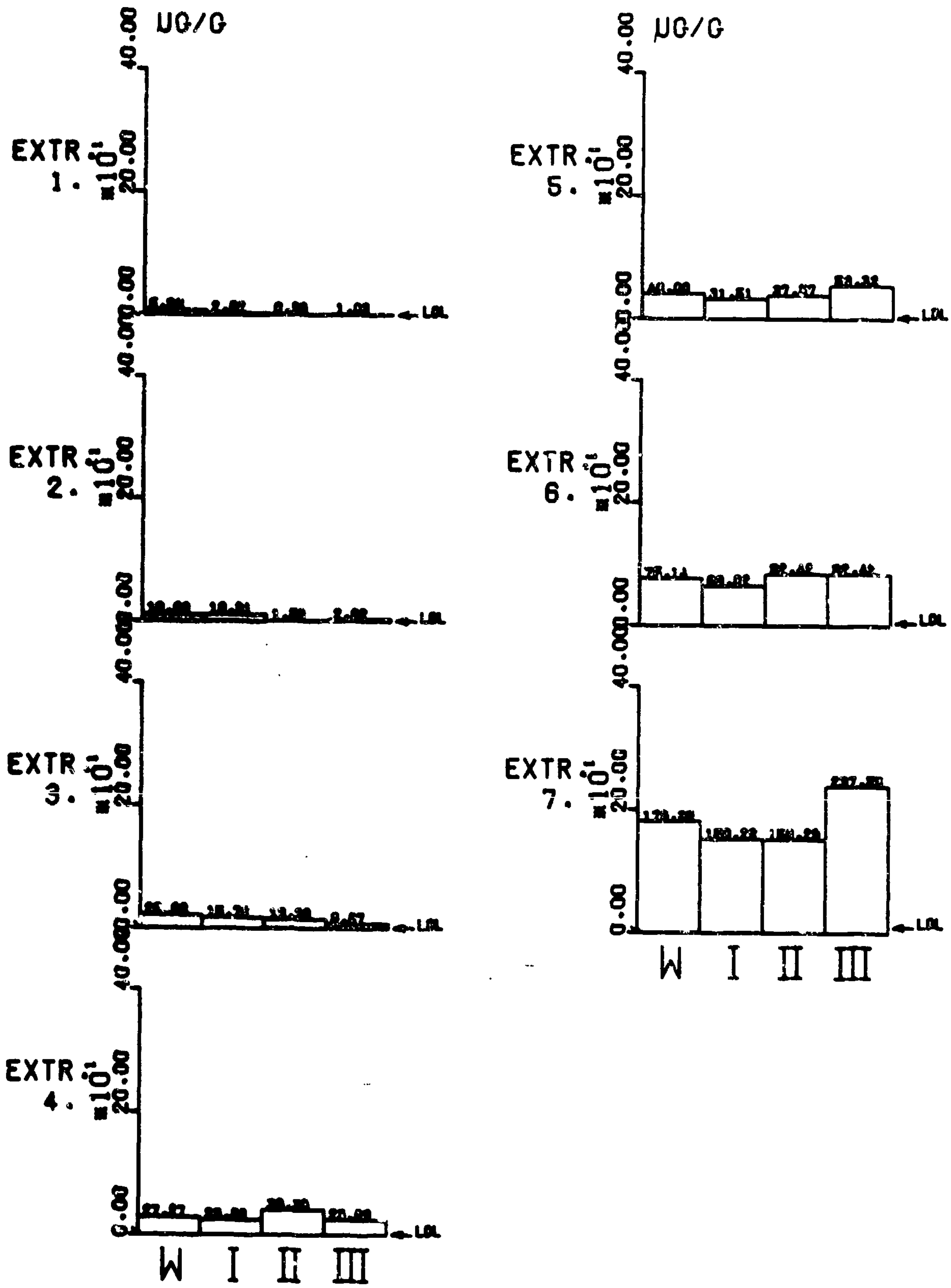


FIGURE 84. WEIGHT OF FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE ON CHALMERS SOIL.

TABLE 44. FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	2.93	5.86										
	I	.91	1.82	4.04	5.86	4.04	.69	.69	.31	127.63	89.55	2.22	65.77
	II	.43	.87	.95	1.82	.95	.52	.52	.48	263.58	89.78	1.09	47.54
	III	.42	.84	.03	.87	.03	.03	.03	.97	272.02	89.79	.04	2.07
	I+II			2.49	2.93	2.49	.85	.85	.15	1055.71	89.95	5.74	80.12
	I+II+III			1.67	1.95	1.67	.86	.86	.14	2453.00	89.98	5.99	80.52
2	W	3.53	10.60										
	I	3.03	9.09	1.51	16.46	5.55	.14	.34	.86	25.69	87.77	.61	31.43
	II	1.04	3.11	5.98	10.91	6.93	.66	.64	.34	75.64	89.24	2.23	65.87
	III	.51	1.53	1.58	3.97	1.61	.51	.40	.49	158.05	89.62	1.05	46.38
	I+II			3.75	8.23	6.24	.71	.76	.29	297.67	89.81	4.02	76.03
	I+II+III			3.02	5.49	4.70	.86	.86	.14	1350.26	89.96	9.21	83.80
3	W	3.33	20.00										
	I	1.72	10.30	9.70	36.46	15.25	.48	.42	.52	23.61	87.57	1.48	55.96
	II	1.72	10.30	.00	21.21	6.93	.00	.33	1.00	22.80	87.49	.67	33.94
	III	.90	5.39	4.91	14.28	6.51	.48	.46	.52	43.48	88.68	1.21	50.39
	I+II			4.85	18.23	11.09	.48	.61	.52	90.68	89.37	2.15	65.09
	I+II+III			4.87	12.15	9.57	.73	.79	.27	385.79	89.85	5.32	79.36
4	W	2.27	27.27										
	I	2.53	30.30	-3.03	63.73	12.22	-.11	.19	1.11	7.93	82.81	.40	21.97
	II	2.37	28.48	1.82	51.51	8.75	.06	.17	.94	8.31	83.14	.31	17.08
	III	1.77	21.21	7.27	42.76	13.79	.26	.32	.74	11.40	84.99	.65	33.02
	I+II			-.61	31.87	10.49	-.04	.33	1.04	32.76	88.25	.74	36.37
	I+II+III			2.02	21.24	11.59	.22	.55	.78	98.39	89.42	1.64	58.61
5	W	1.67	40.00										
	I	2.53	60.60	-20.60	103.73	-8.38	-.52	-.08	1.52	3.62	74.57	-.14	-7.88
	II	2.73	65.45	-4.85	112.11	3.90	-.08	.03	1.08	3.54	74.24	.06	3.41
	III	2.32	55.75	9.70	108.21	23.48	.15	.22	.85	4.51	77.50	.42	22.84
	I+II			-12.73	51.86	-2.24	-.64	-.04	1.64	13.87	85.88	-.07	-3.92
	I+II+III			-5.25	34.58	6.33	-.39	.18	1.39	37.15	88.46	.34	18.82
6	W	1.57	75.14										
	I	1.31	63.02	12.12	178.87	3.74	.16	.02	.84	3.68	74.79	.06	3.39
	II	1.26	60.60	2.42	175.13	6.33	.04	.04	.96	3.87	75.50	.10	5.96
	III	1.15	55.27	5.33	168.91	28.82	.09	.17	.91	4.65	77.86	.52	27.54
	I+II			7.27	89.44	5.03	.19	.06	.81	15.22	86.24	.17	9.43
	I+II+III			6.63	59.62	12.96	.26	.22	.74	37.83	88.49	.70	35.13
7	W	1.87	179.38										
	I	1.67	159.98	19.39	358.25	23.13	.11	.06	.89	1.57	57.50	.14	8.23
	II	1.67	159.98	.00	335.12	6.33	.00	.02	1.00	1.46	55.68	.04	2.26
	III	2.17	208.46	-48.48	328.79	-19.66	-.30	-.06	1.30	1.00	44.98	-.09	-5.39
	I+II			9.70	179.12	14.73	.11	.08	.89	5.88	80.36	.18	10.43
	I+II+III			-9.70	119.42	3.26	-.16	.03	1.16	9.89	84.23	.05	2.69

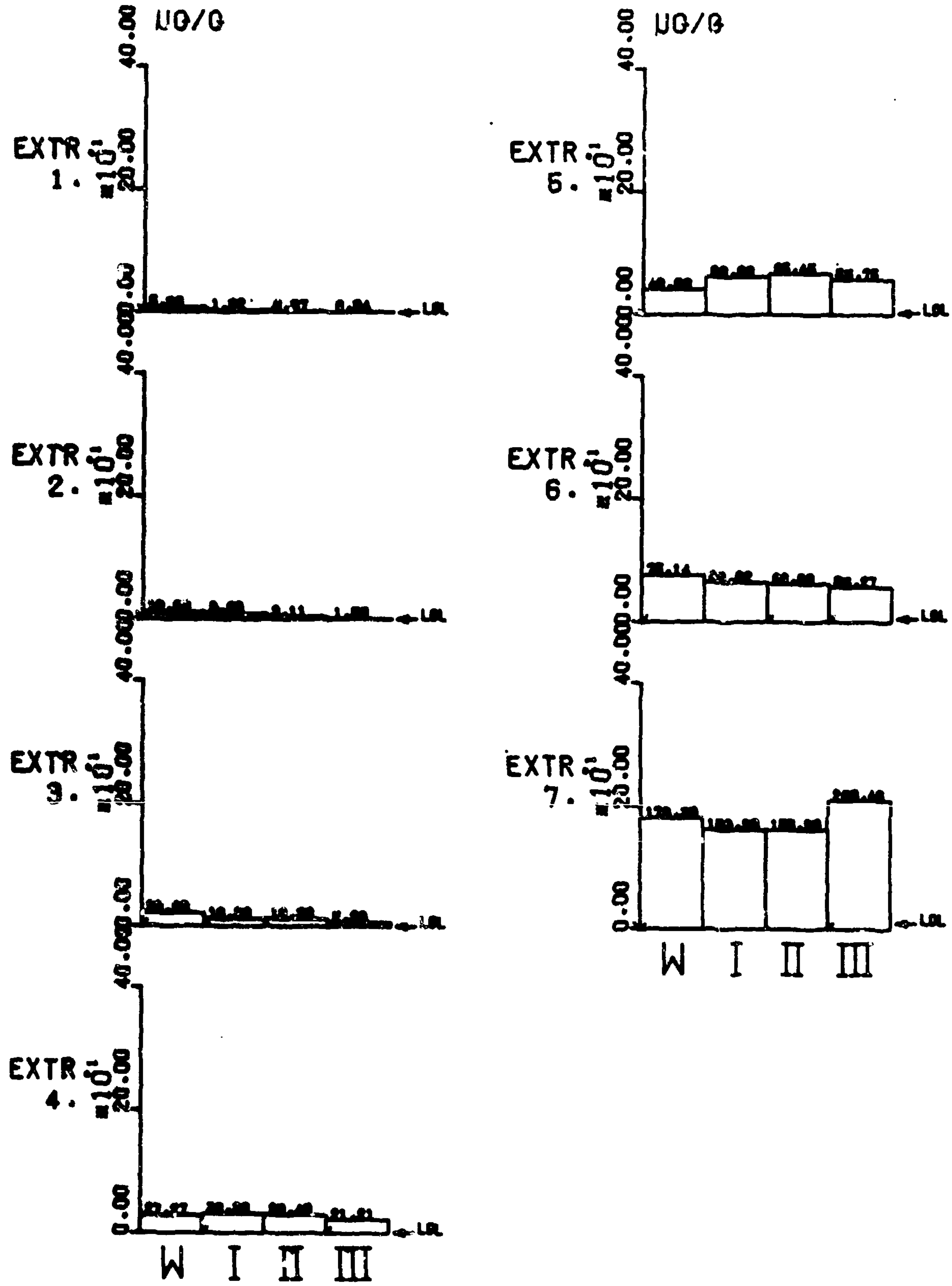


FIGURE 85. WEIGHT OF FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE ON DAVIDSON SOIL.

TABLE 45. FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE ON NICHOLSON SOIL.

EXT. NO.	LAYER	ANT. PENETR. UG/ML	ANT. PENETR. UG/G	ANT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	2.93	5.86										
	I	1.41	2.83	3.03	5.86	3.03	.52	.52	.48	552.70	89.90	1.07	46.97
	II	.35	.71	2.12	2.83	2.12	.75	.75	.25	2209.51	89.97	3.00	71.57
	III	1.11	2.22	-1.51	.71	-1.51	-2.14	-2.14	3.14	761.39	89.92	-.68	-34.29
	I+II			2.58	2.93	2.58	.88	.88	.12	8833.31	89.99	7.29	82.18
	I+II+III			1.21	1.95	1.21	.62	.62	.38	6320.27	89.99	1.64	58.57
2	W	3.53	10.60										
	I	5.25	15.76	-5.15	16.46	-2.12	-.49	-.13	1.49	98.80	89.42	-.13	-7.67
	II	.57	1.70	14.06	18.58	16.10	.89	.87	.11	920.91	89.94	9.54	84.01
	III	.31	.94	.76	2.40	-.76	.45	-.32	.55	1660.00	89.97	-.81	-38.80
	I+II			4.45	8.23	7.03	.84	.85	.16	3605.00	89.98	8.29	83.12
	I+II+III			3.22	5.49	4.43	.91	.81	.09	14961.46	90.00	14.16	85.96
3	W	3.33	20.00										
	I	4.14	24.85	-4.05	36.46	-6.97	-.24	-.19	1.24	62.51	89.08	-.28	-15.67
	II	2.93	17.57	7.27	43.43	23.45	.29	.54	.71	90.10	89.36	1.33	53.15
	III	.40	2.91	14.67	19.98	13.91	.83	.70	.17	541.00	89.89	4.78	78.19
	I+II			1.21	10.23	8.24	.12	.45	.88	356.01	89.84	.94	43.17
	I+II+III			5.70	12.15	10.13	.85	.83	.15	4037.18	89.99	10.45	84.53
4	W	2.27	27.27										
	I	2.53	30.30	-3.03	63.73	-10.00	-.11	-.16	1.11	51.16	88.88	-.33	-18.26
	II	3.33	40.00	-9.70	73.73	13.76	-.32	.19	1.32	39.35	88.54	.34	18.98
	III	1.87	22.42	17.57	59.97	31.40	.44	.52	.56	76.76	89.19	1.40	54.54
	I+II			-6.36	31.87	1.80	-.47	.66	1.47	156.11	89.63	.09	5.37
	I+II+III			1.62	21.24	11.75	.18	.55	.82	627.74	89.91	1.57	57.53
5	W	1.67	40.30										
	I	2.63	63.02	-23.03	103.73	-33.03	-.58	-.32	1.58	24.23	87.64	-.52	-27.66
	II	2.02	48.48	14.54	136.75	28.30	.23	.21	.77	32.76	88.25	.58	30.27
	III	3.20	70.70	-30.30	100.45	1.10	-.62	.01	1.62	19.82	87.11	.02	.86
	I+II			-4.24	51.86	-2.36	-.21	-.05	1.21	128.62	89.55	-.10	-5.57
	I+II+III			-12.93	34.50	-1.18	-.97	-.03	1.97	178.17	89.68	-.04	-2.58
6	W	1.57	75.14										
	I	1.82	87.26	-12.12	170.07	-45.15	-.16	-.25	1.16	17.36	86.79	-.52	-27.36
	II	1.87	89.69	-2.42	224.82	25.00	-.03	.12	1.03	17.68	86.76	.29	16.09
	III	2.07	79.38	-9.70	190.14	-8.51	-.11	-.04	1.11	15.61	86.33	-.09	-4.90
	I+II			-7.27	89.44	-9.64	-.19	-.11	1.19	69.36	89.17	-.21	-12.13
	I+II+III			-8.00	59.62	-9.26	-.32	-.16	1.32	140.99	89.57	-.28	-15.62
7	W	1.87	179.30										
	I	1.62	155.14	24.24	358.25	-20.91	.14	-.06	.86	9.92	84.24	-.13	-7.68
	II	1.72	164.83	-9.70	379.15	16.18	-.06	.04	1.06	9.56	84.63	.10	5.61
	III	1.67	159.90	4.85	362.97	-3.67	.03	-.01	.97	9.73	84.13	-.02	-1.31
	I+II			7.27	179.12	-2.36	.08	-.01	.92	37.83	88.49	-.03	-1.64
	I+II+III			6.46	119.42	-2.80	.11	-.02	.89	87.71	89.35	-.05	-3.00

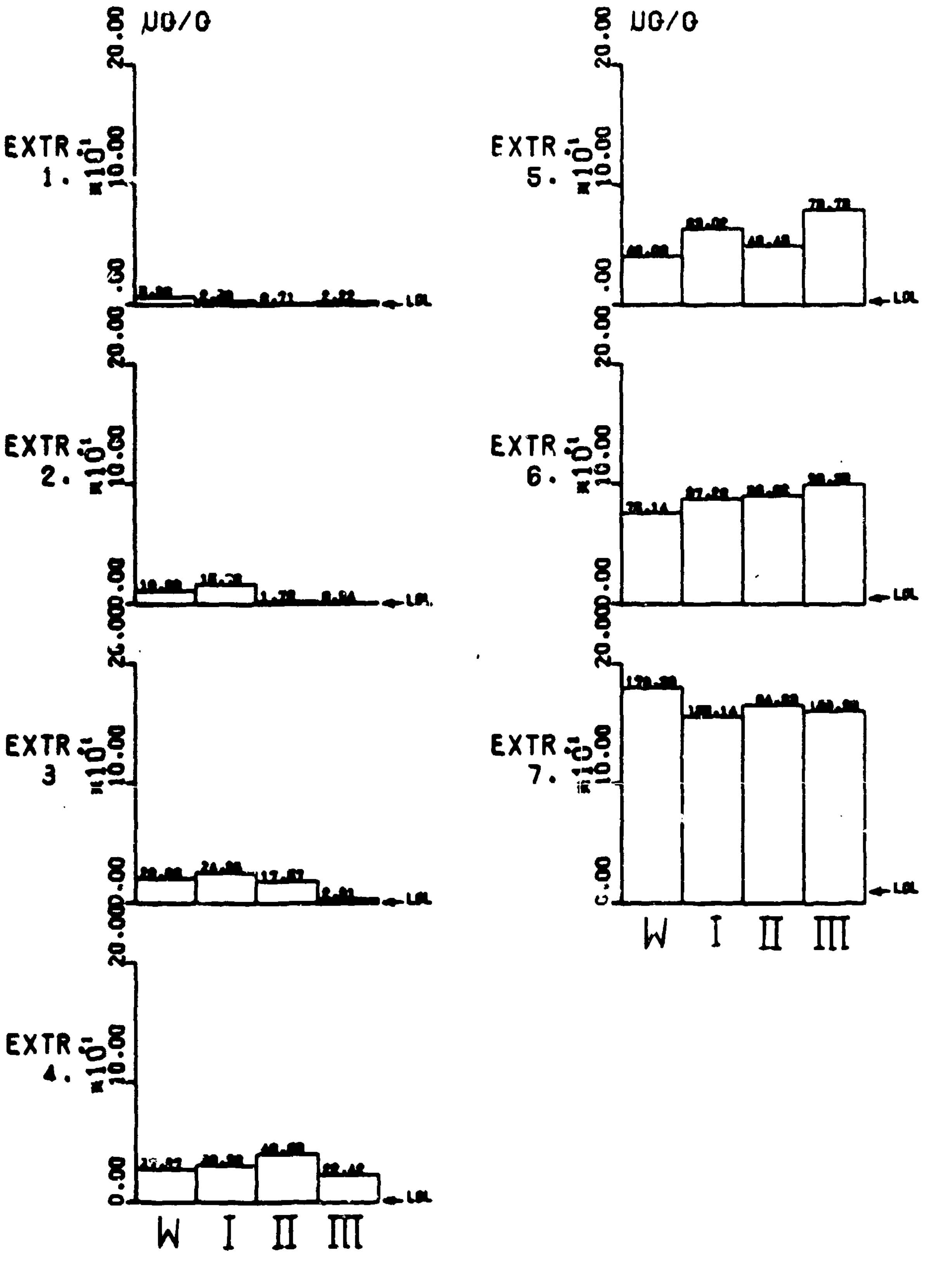


FIGURE 86. WEIGHT OF FLUORINE FROM WHITE PHOSPHORUS PRODUCTION WASTE ON NICHOLSON SOIL.

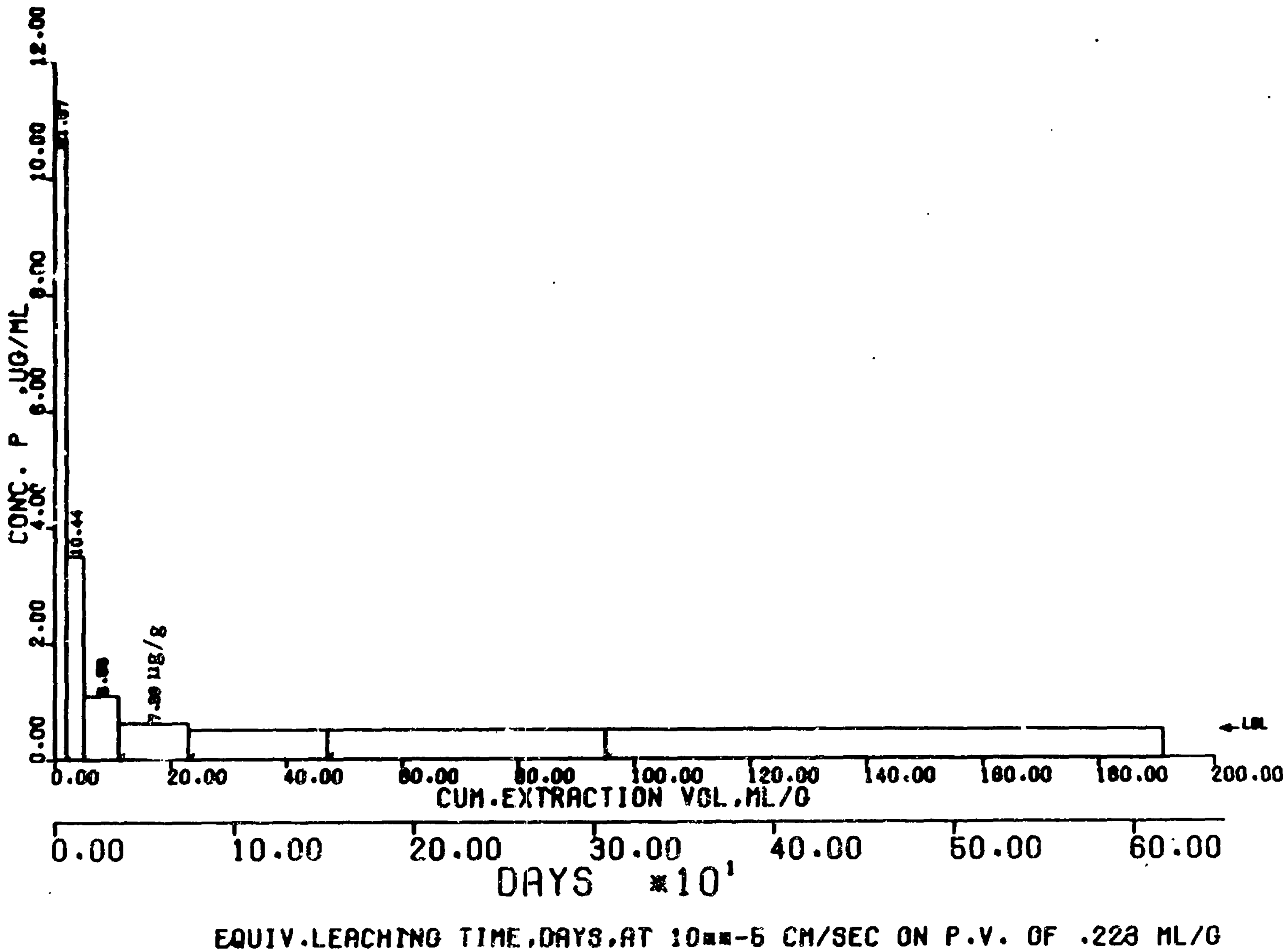


FIGURE 87. EXTRACTION OF PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE.

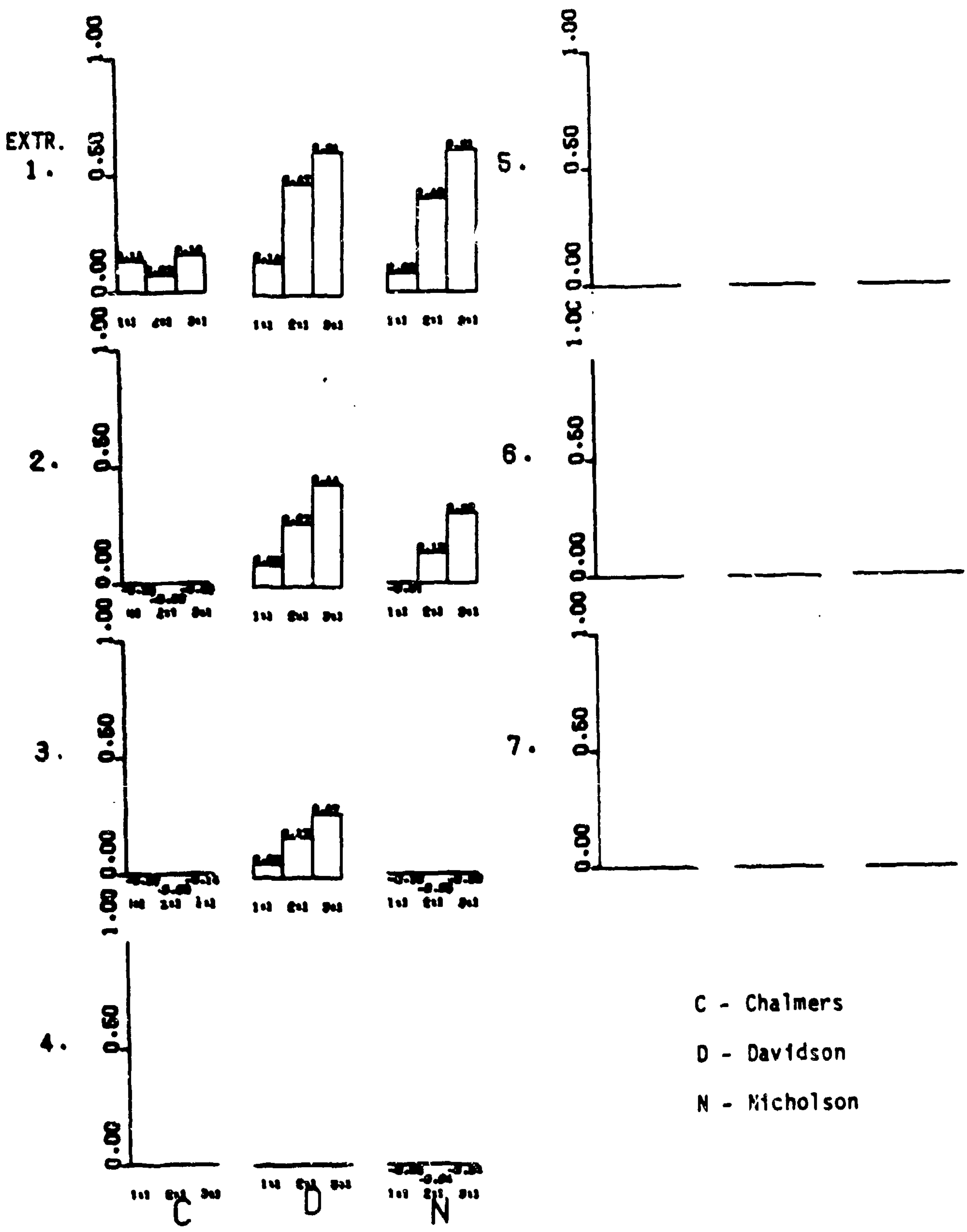


FIGURE 88. COMPARING FRACTION PHOSPHORUS RETAINED BY SOILS FROM WHITE PHOSPHORUS PRODUCTION WASTE LEACHATE.

TABLE 46. PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	10.53	21.07										
	I	9.14	18.28	2.79	21.07	2.79	.13	.13	.87	25.32	87.74	.15	8.67
	II	9.77	19.53	-1.25	18.28	-1.25	-.07	-.07	1.07	23.49	87.56	-.06	-3.67
	III	8.88	17.76	1.78	19.53	1.78	.09	.09	.91	26.01	87.80	.10	5.72
	I+II			.77	10.53	.77	.07	.07	.93	94.28	89.39	.08	4.49
	I+II+III			1.10	7.02	1.10	.16	.16	.84	233.35	89.75	.19	10.57
2	W	3.48	10.44										
	I	4.77	14.30	-3.06	31.51	-1.00	-.37	-.03	1.37	32.09	88.22	-.08	-4.30
	II	4.67	14.00	.30	32.50	-.95	.02	-.03	.98	32.79	88.25	-.07	-3.88
	III	4.92	14.77	-.77	33.53	1.00	-.06	.03	1.06	31.21	88.16	.07	3.89
	I+II			-1.70	15.75	-1.01	-.34	-.06	1.34	131.30	89.56	-.14	-8.23
	I+II+III			-1.44	10.50	-.34	-.42	-.03	1.42	280.21	89.80	-.07	-3.95
3	W	1.10	6.58										
	I	1.37	8.24	-1.67	38.00	-2.74	-.25	-.07	1.25	55.40	88.97	-.33	-18.40
	II	1.34	8.03	.21	40.02	-.74	.03	-.02	.77	57.20	89.00	-.09	-5.25
	III	1.83	11.00	-2.97	41.56	-1.96	-.37	-.05	1.37	41.64	88.62	-.18	-10.13
	I+II			-.73	19.04	-1.74	-.22	-.09	1.22	228.72	89.75	-.43	-23.43
	I+II+III			-1.47	12.69	-1.01	-.67	-.14	1.67	375.91	89.85	-.49	-26.33
4	W	.62	7.39										
	I	<.50	<6.06		45.40								
	II	.53	6.30										
	III	(.50	(6.06										
	I+II												
	I+II+III												
5	W	(.50	(12.12										
	I	(.50	(12.12										
	II	(.50	(12.12										
	III	(.50	(12.12										
	I+II												
	I+II+III												
6	W	(.50	(24.24										
	I	(.50	(24.24										
	II	(.50	(24.24										
	III	(.50	(24.24										
	I+II												
	I+II+III												
7	W	(.50	(48.48										
	I	(.50	(48.48										
	II	(.50	(48.48										
	III	(.50	(48.48										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

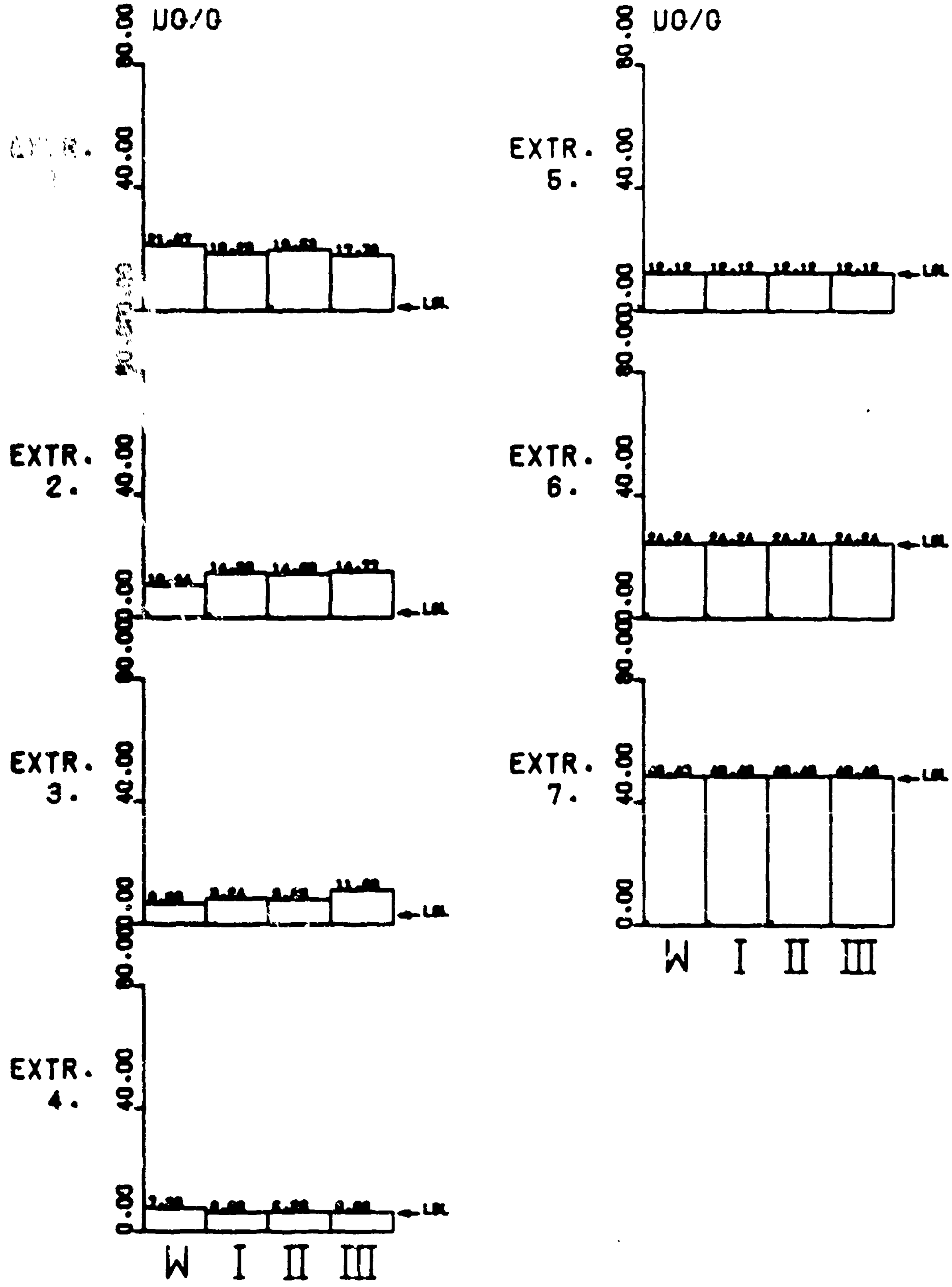


FIGURE 89. WEIGHT OF PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE ON CHALMERS SOIL.

TABLE 47. PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	10.53	21.07										
	I	9.05	10.10	2.97	21.07	2.97	.14	.14	.86	26.05	87.80	.16	9.32
	II	5.53	11.07	7.03	10.10	7.03	.39	.39	.61	42.96	88.67	.64	32.42
	III	4.10	8.20	2.87	11.07	2.87	.26	.26	.74	57.40	89.00	.35	19.28
	I+II			5.00	10.53	5.00	.47	.47	.53	170.20	89.66	.90	42.09
	I+II+III			4.29	7.02	4.29	.61	.61	.39	515.70	89.89	1.57	57.49
2	W	3.40	10.44										
	I	3.52	10.56	-.12	31.51	2.85	-.01	.09	1.01	44.64	88.72	.27	15.10
	II	4.01	12.03	-1.47	20.66	5.56	-.14	.19	1.14	39.41	88.55	.46	24.81
	III	3.19	9.56	2.47	23.10	5.34	.21	.23	.79	49.57	88.84	.56	29.10
	I+II			-.00	15.75	4.20	-.15	.27	1.15	156.49	89.63	.70	34.95
	I+II+III			.29	10.50	4.58	.00	.44	.92	442.51	89.87	1.44	55.10
3	W	1.10	6.58										
	I	1.21	7.27	-.70	38.00	2.15	-.11	.06	1.11	64.72	89.11	.38	16.40
	II	1.43	8.57	-1.30	35.93	4.26	-.18	.12	1.18	55.13	88.96	.50	26.40
	III	1.67	10.00	-1.42	31.67	3.91	-.17	.12	1.17	47.25	88.79	.39	21.30
	I+II			-1.00	19.04	3.20	-.30	.17	1.30	219.29	89.74	.75	36.77
	I+II+III			-1.14	12.69	3.44	-.52	.27	1.52	422.72	89.86	1.03	45.91
4	W	.62	7.39										
	I	<.50	<6.06										
	II	<.50	<6.06										
	III	.60	7.21										
	I+II												
	I+II+III												
5	W	(.50	(12.12										
	I	(.50	(12.12										
	II	(.50	(12.12										
	III	(.50	(12.12										
	I+II												
	I+II+III												
6	W	(.50	(24.24										
	I	(.50	(24.24										
	II	(.50	(24.24										
	III	(.50	(24.24										
	I+II												
	I+II+III												
7	W	(.50	(40.40										
	I	(.50	(40.40										
	II	(.50	(40.40										
	III	.59	56.72										
	I+II												
	I+II+III												

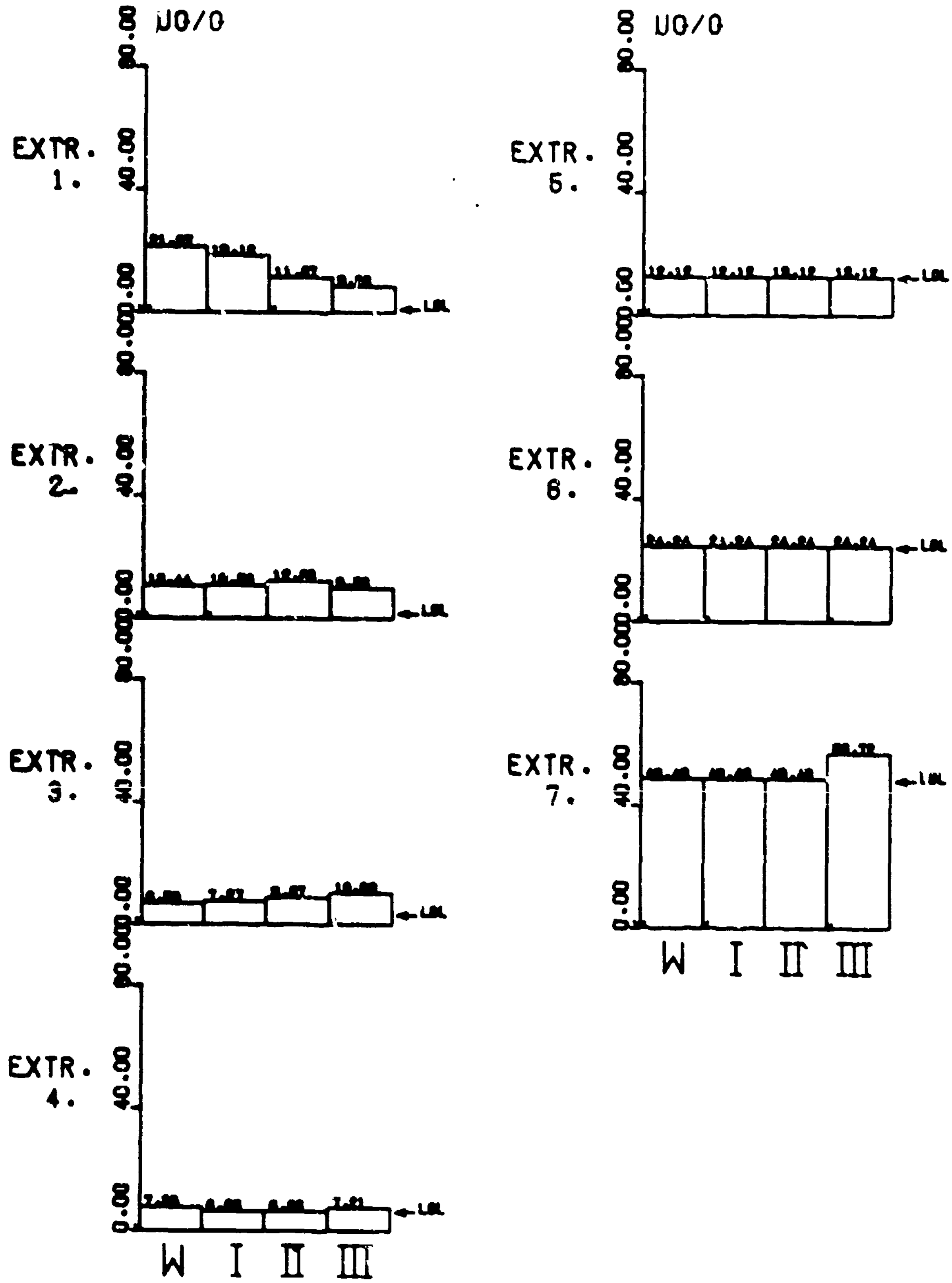


FIGURE 90. WEIGHT OF PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE ON DAVIDSON SOIL.

TABLE 48. PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE ON NICHOLSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	10.53	21.07										
	I	9.70	19.40	1.67	21.07	1.67	.08	.08	.92	88.22	89.35	.09	4.91
	II	6.34	12.68	6.73	19.40	6.73	.35	.35	.65	135.44	89.58	.53	27.95
	III	4.15	8.29	4.38	12.68	4.38	.35	.35	.65	206.75	89.72	.53	27.86
	I+II			4.20	10.53	4.20	.40	.40	.60	540.20	89.89	.66	33.51
	I+II+III			4.26	7.02	4.26	.61	.61	.39	1857.52	89.97	1.54	57.02
2	W	3.48	10.44										
	I	4.11	12.33	-1.89	31.51	-.23	-.10	-.01	1.10	138.64	89.59	-.02	-1.06
	II	4.96	14.88	-2.55	31.73	4.18	-.21	.13	1.21	115.22	89.50	.28	15.70
	III	4.62	13.86	1.02	27.55	5.40	.07	.20	.93	123.75	89.54	.39	21.28
	I+II			-2.22	15.75	1.98	-.43	.13	1.43	460.03	89.88	.27	14.88
	I+II+III			-1.14	10.50	3.12	-.33	.30	1.33	1110.00	89.95	.67	34.01
3	W	1.10	6.58										
	I	1.67	10.03	-3.45	38.08	-3.68	-.53	-.10	1.53	170.13	89.66	-.37	-20.16
	II	2.06	12.33	-2.30	41.76	1.88	-.23	.04	1.23	138.81	89.59	.15	8.66
	III	2.68	16.06	-3.73	39.88	1.67	-.30	.04	1.30	106.59	89.46	.10	5.94
	I+II			-2.00	19.04	-.90	-.80	-.05	1.80	554.50	89.90	-.15	-8.32
	I+II+III			-3.16	12.69	-.04	-1.44	-.00	2.44	958.33	89.94	-.01	-.47
4	W	.62	7.39										
	I	<.50	<6.06	1.33	45.48	-2.35	.18	-.05	.82	281.79	89.80	-.39	-21.18
	II	.60	7.21	-1.15	47.82	.73	-.19	.02	1.19	237.23	89.76	.10	5.76
	III	.75	8.97	-1.76	47.10	-.09	-.24	-.00	1.24	190.65	89.70	-.01	-.55
	I+II			.09	22.74	-.81	.02	-.04	.98	948.27	89.94	-.22	-12.67
	I+II+III			-.53	15.16	-.57	-.21	-.04	1.21	1715.76	89.97	-.19	-10.78
5	W	<.50	<12.12										
	I	<.50	<12.12										
	II	<.50	<12.12										
	III	.57	13.70										
	I+II												
	I+II+III												
6	W	<.50	<24.24										
	I	<.50	<24.24										
	II	.57	27.15										
	III	<.50	<24.24										
	I+II												
	I+II+III												
7	W	<.50	<48.48										
	I	<.50	<48.48										
	II	<.50	<48.48										
	III	<.50	<48.48										
	I+II												
	I+II+III												

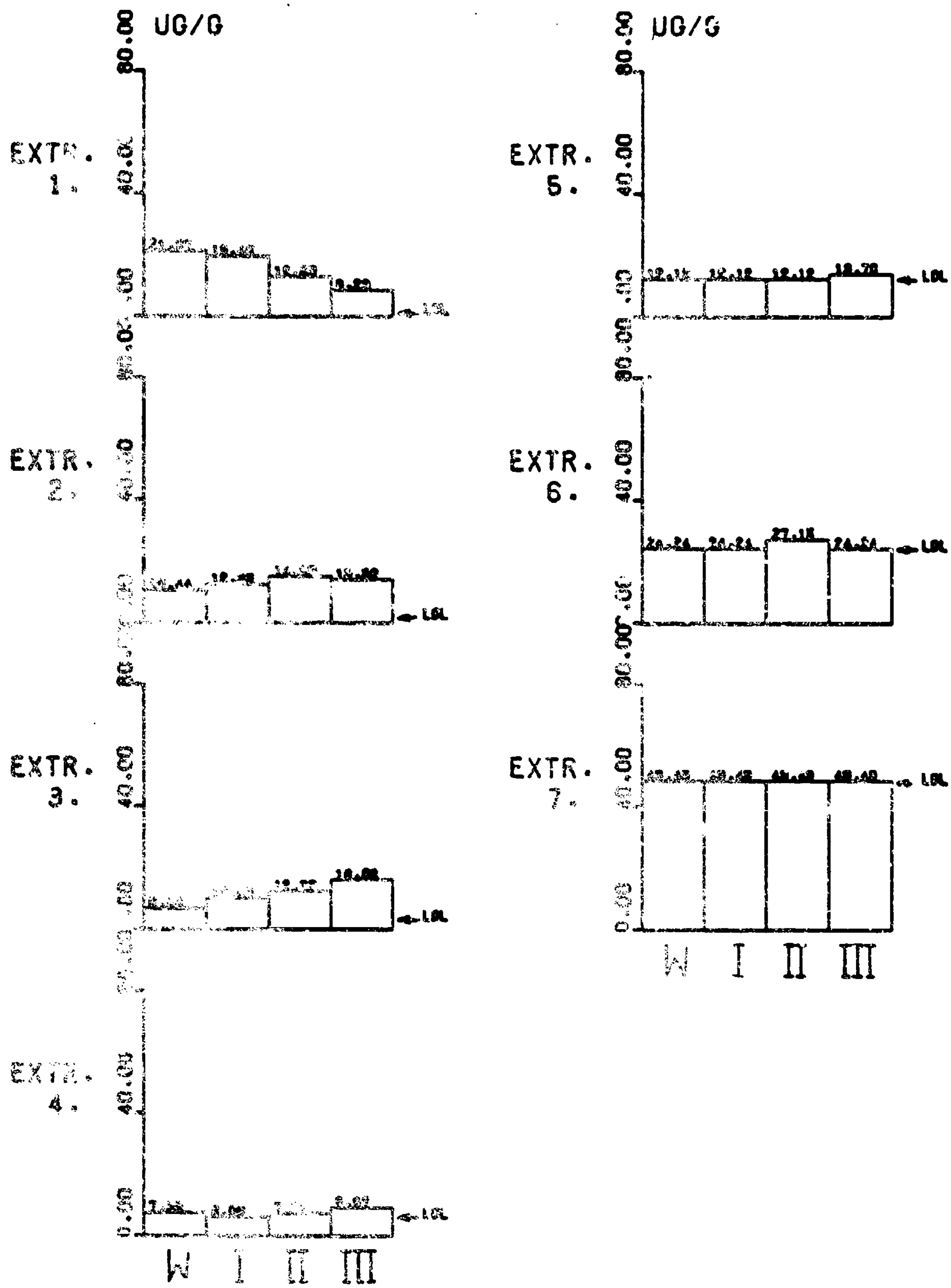


FIGURE 91. WEIGHT OF PHOSPHORUS FROM WHITE PHOSPHORUS PRODUCTION WASTE ON NICHOLSON SOIL.

SECONDARY ZINC SMELTER CINDERS

The secondary smelting of zinc produced cinders that had been deposited in an open dumping area. The age of the sample tested was not known, but they may have been exposed to leaching for several years. Table 49 and Figures 92 to 97 show that this sample of cinders was not very soluble and the leachate was only slightly acidic. However, the conductance histograms indicate that some substances in the soil were solubilized by this extract.

TABLE 49. LEACHABILITY OF SECONDARY ZINC SMELTER CINDERS

Element	Initial Conc. (µg/ml)	When Concentration Levels Off Conc. (µg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days	Total Weight Extracted (µg/g waste)	Percentage Extracted
Cd	0.34	0.04	4	23	75	1.7	2.8
Pb	0.34	0.13	7	190	620	≈28.	≈0.2
Ni	0.15	0.08	4	23	75	1.9	0.10
Zn	41.	2.1	7	190	620	707.	1.4

Measurement	Initial	Final	Estim.Tot.Extr. (µ equiv/g)
Conduct. (µ mho)	370.	16.	58.
pH	6.7	5.6	--

Cadmium

Figure 98 and Tables 49 to 52 show that the concentration of cadmium in the leachate is low initially and drops rapidly, producing a total of only about 1.7 µg/g which is 2.8 percent of the cadmium present in the cinders. Figures 99 to 102 show that all three soils retain the cadmium well, although precise calculations on the fraction retained cannot be made when the concentration falls below the detection limit.

Lead

The concentration of lead extracted is low (0.34 µg/ml) giving a total of approximately 28 µg/g, or 0.2 percent of the lead in the waste. (Figure 103 and Tables 49, 53 to 55.) So many of the samples were below the detection limit that no attempt was made to calculate and plot the fraction retained by the soil. The weights obtained in each extraction are displayed in Figures 104 to 106.

Nickel

Tables 49, 56 to 58 and Figure 107 show that the concentrations of nickel in the extracts were very low, yielding a total of only 1.9 µg/g, which is 0.10 percent of the amount in the cinders. Figures 108 to 110 show

that the amount of nickel in the soil extracts were generally below the detection limit. For this reason, a set of histograms was not prepared comparing the fractions retained.

Zinc

Zinc was present in the cinder extracts at a low concentration (41 μg/ml decreasing to 2.1 μg/ml), as seen in Table 49 and Figure 111. A total of 707 μg zinc was dissolved per gram of cinders, which represents 0.14 percent of that present in this waste. Tables 59 to 61 and Figures 112 to 115 show that only a few percent of the zinc penetrates the 3:1 soil-to-waste ratio, giving an average concentration of 0.14 μg/ml. All three soils are very similar in performance.

Summary

Aged cinders from a zinc secondary-refining operation yielded low or very low concentrations of cadmium, lead, nickel, and zinc. The sample tested was quite insoluble and only a few tenths of a percent of lead, nickel, and zinc dissolved, and less than three percent of the cadmium was removed by the seven extractions. The effluents from the soils contained very low concentrations of these metals, although previously-retained cadmium was being released.

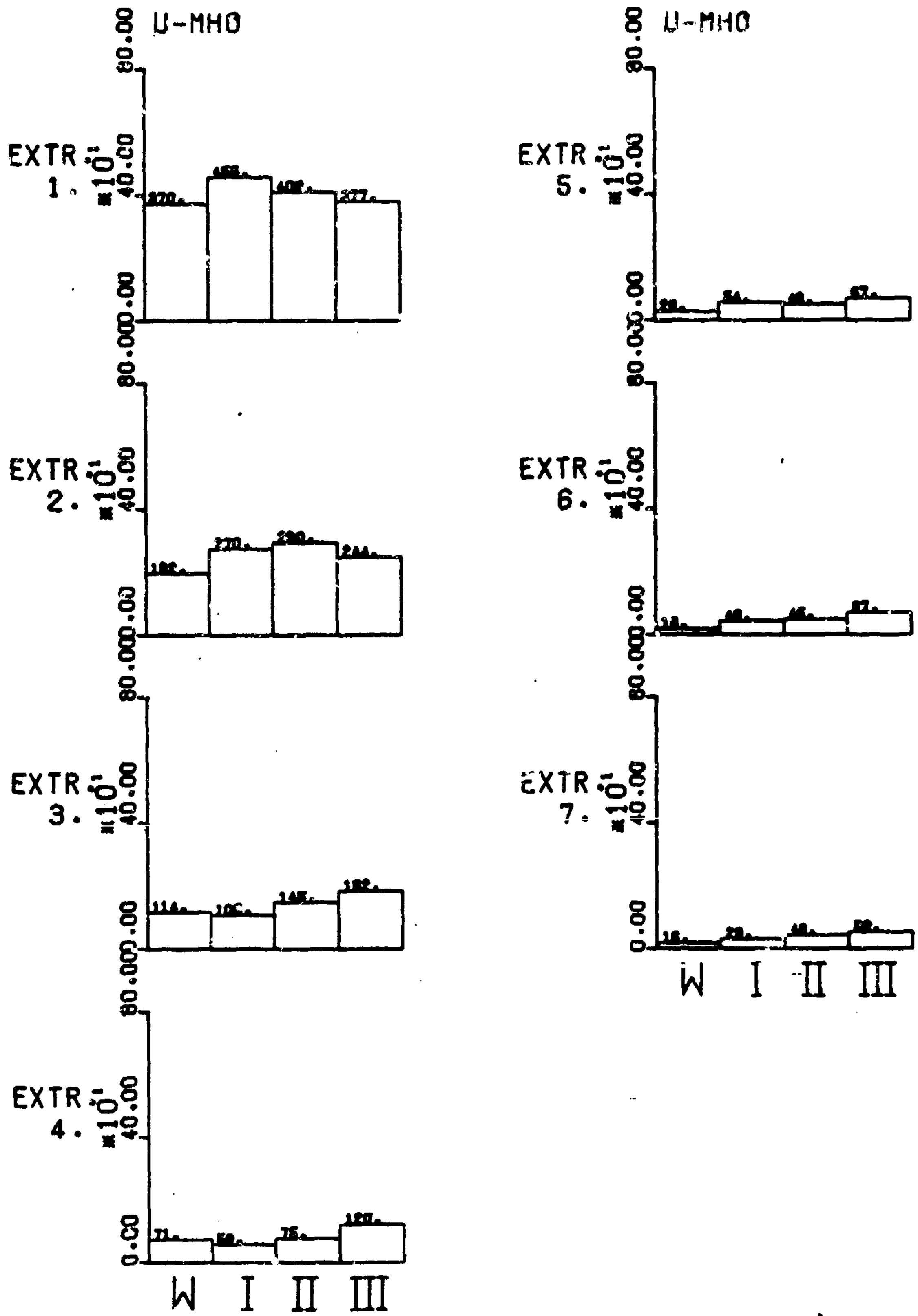


FIGURE 92. CONDUCTANCE OF EXTRACT FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

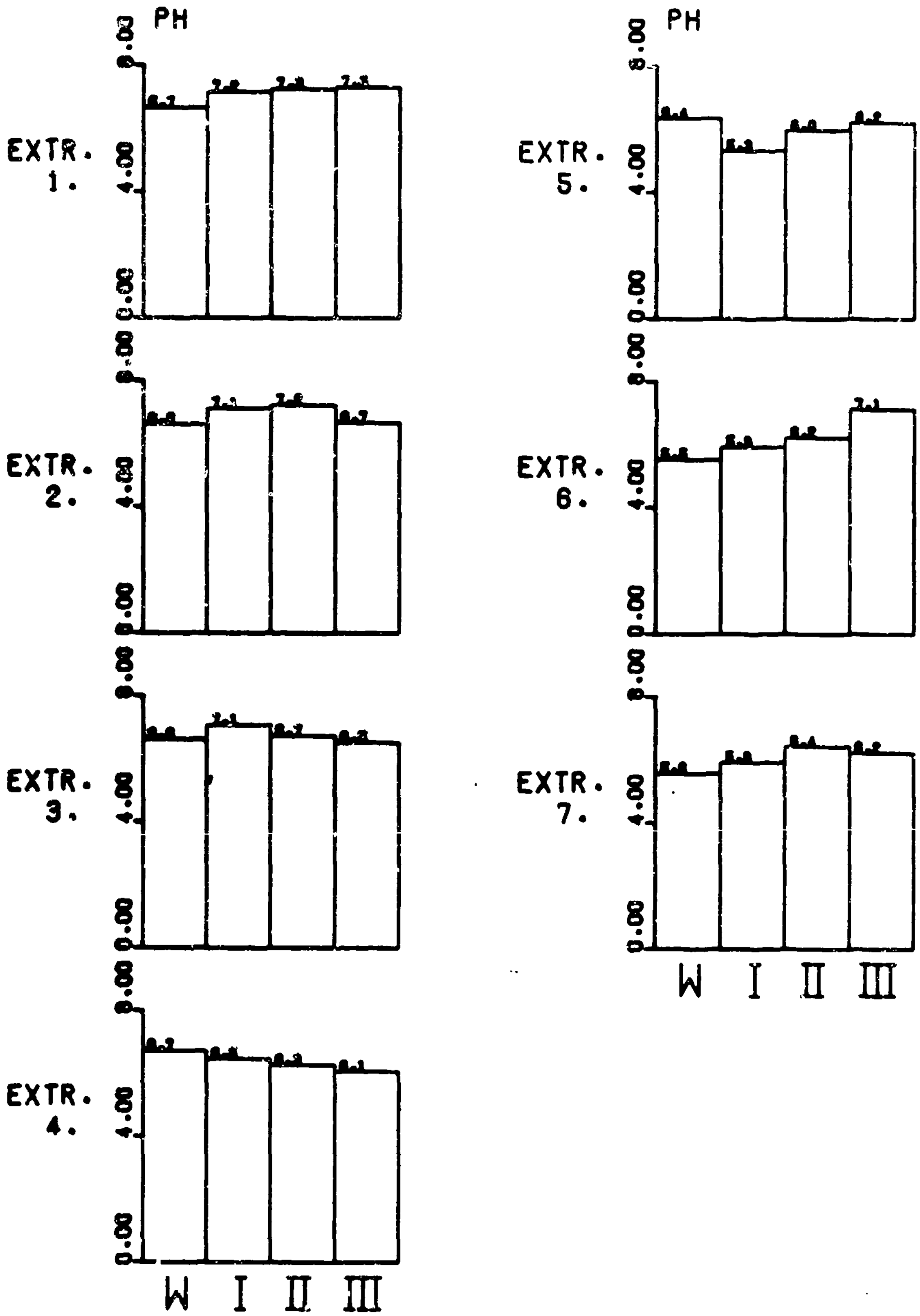


FIGURE 93. pH OF EXTRACT FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

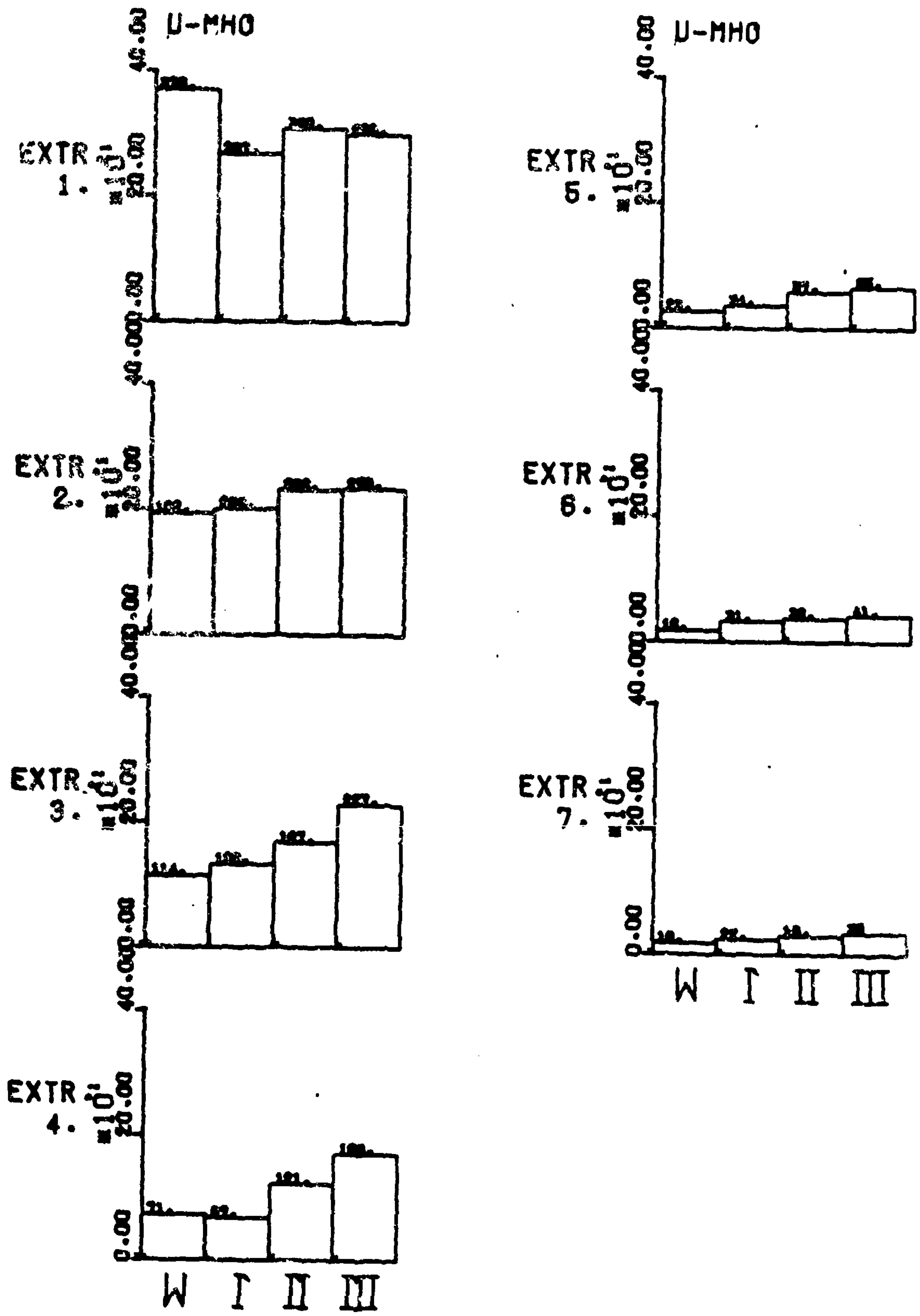


FIGURE 94. CONDUCTANCE OF EXTRACT FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

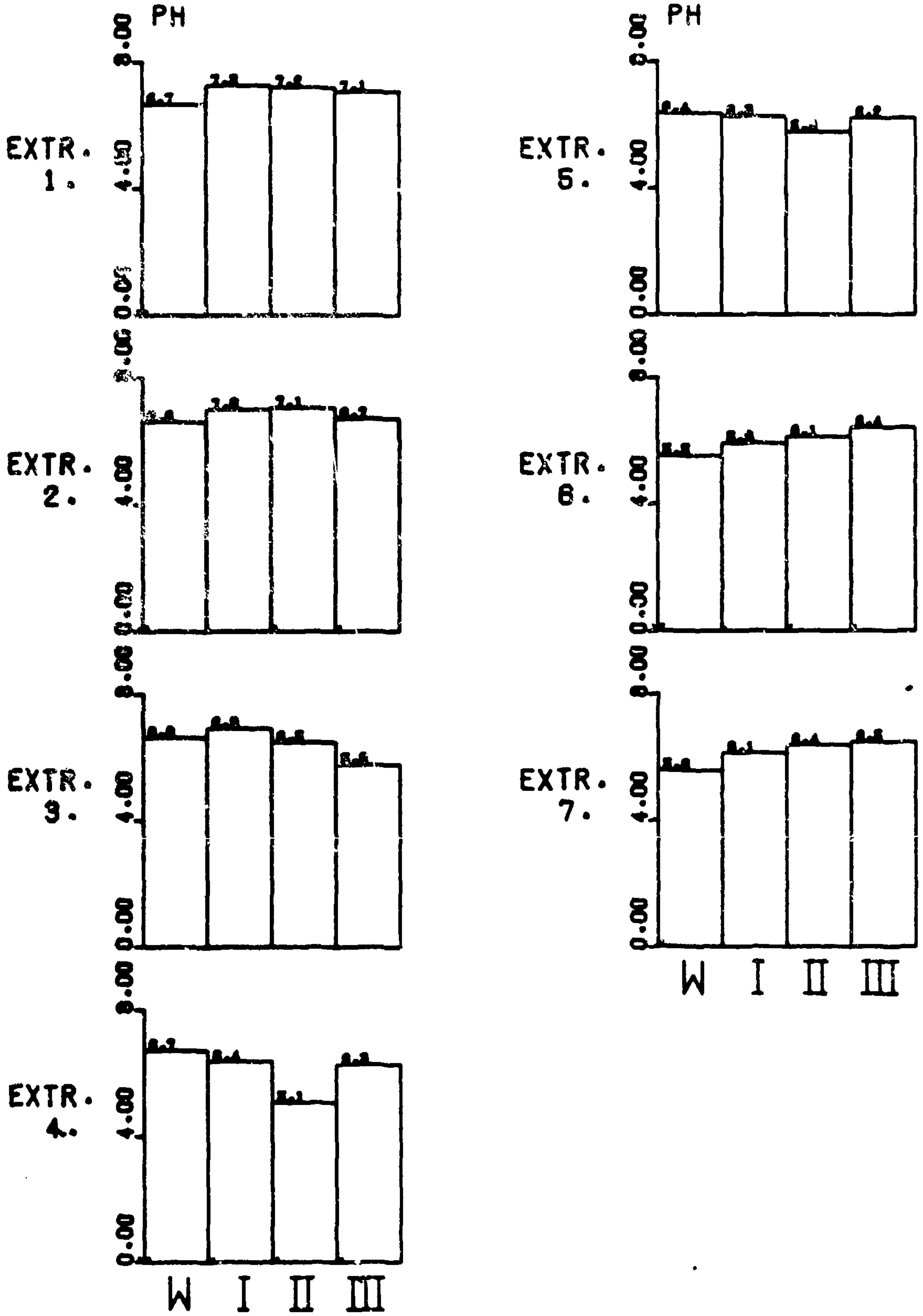


FIGURE 95. pH OF EXTRACT FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

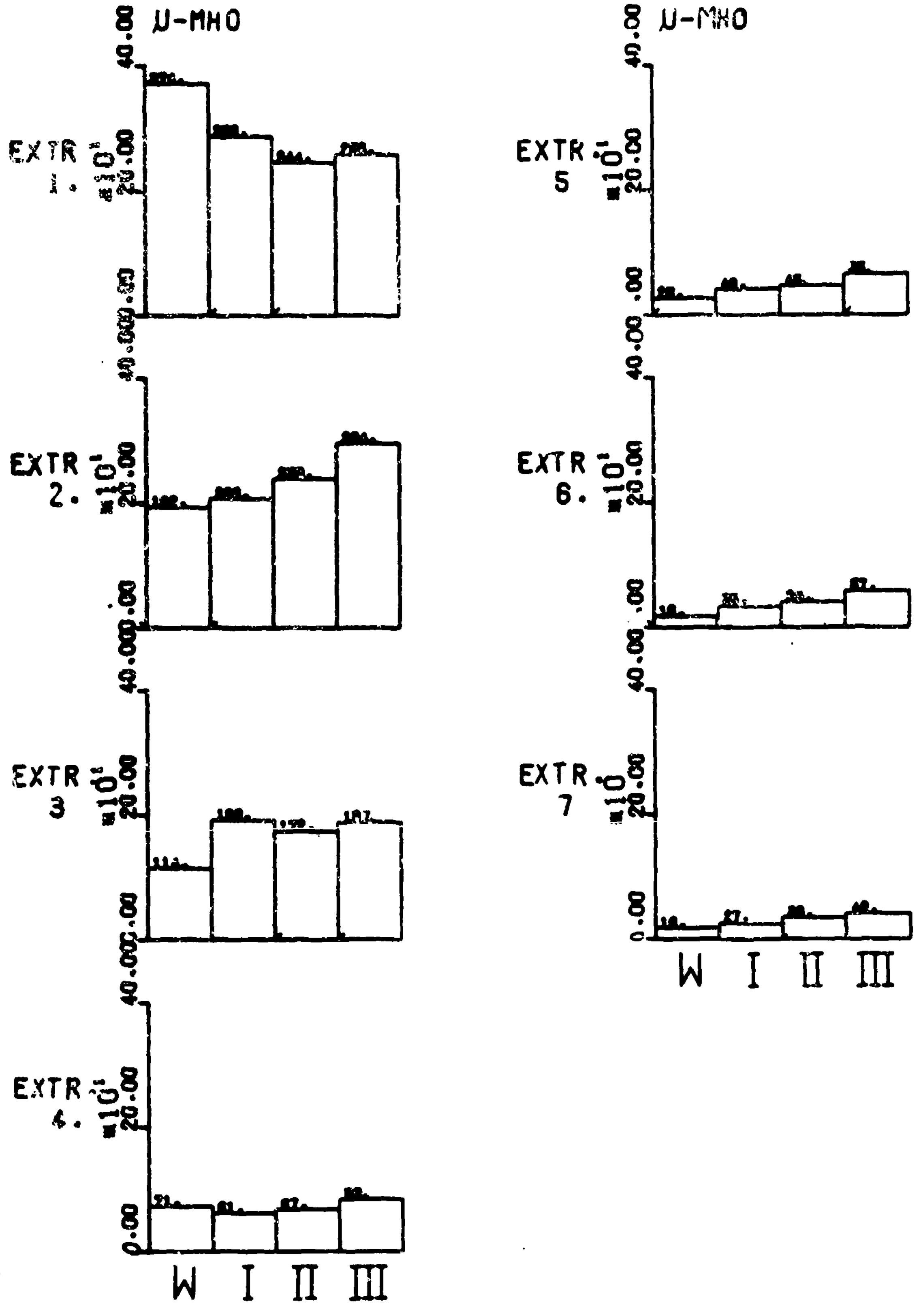


FIGURE 96. CONDUCTANCE OF EXTRACT FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

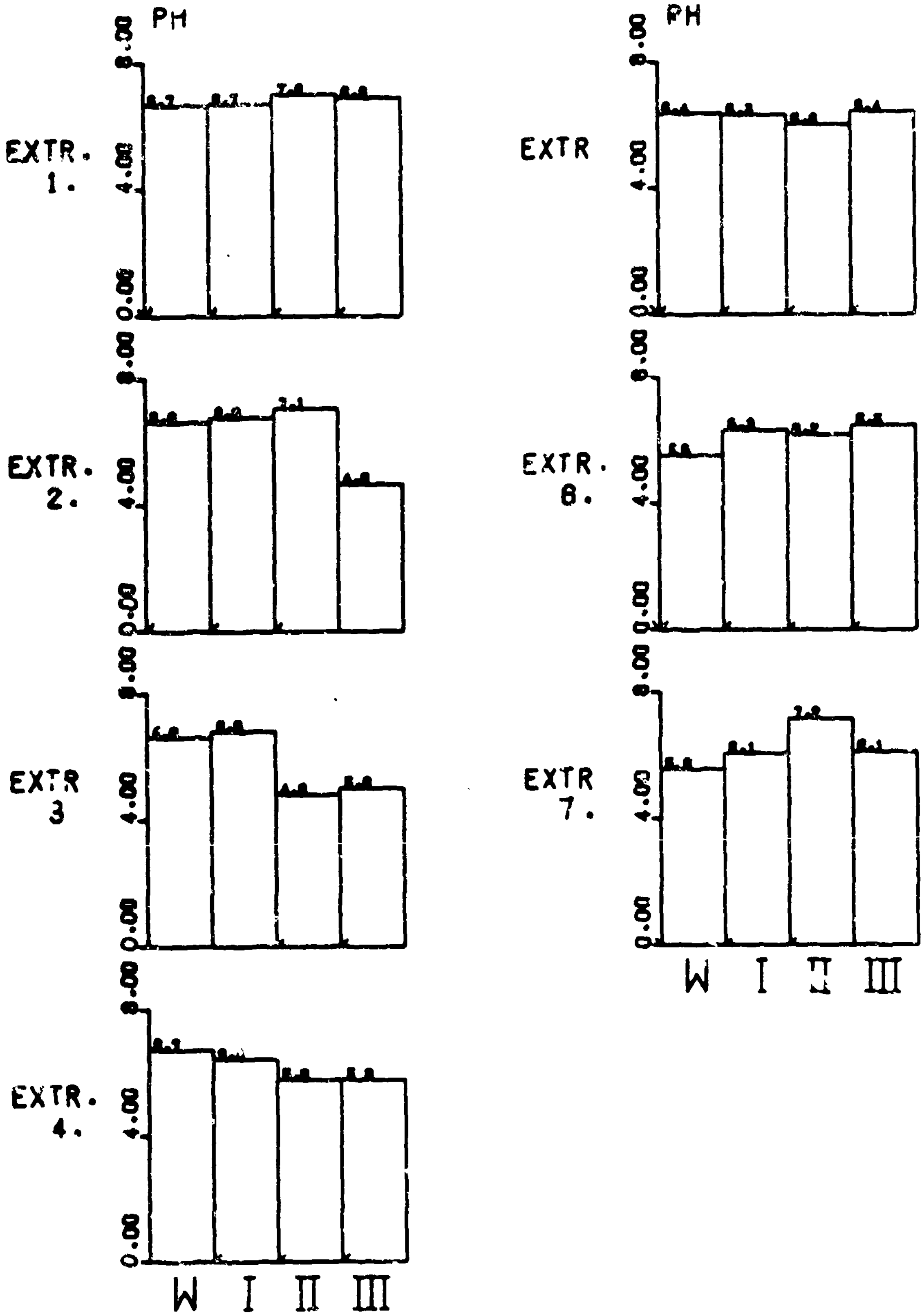


FIGURE 97. pH OF EXTRACT FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

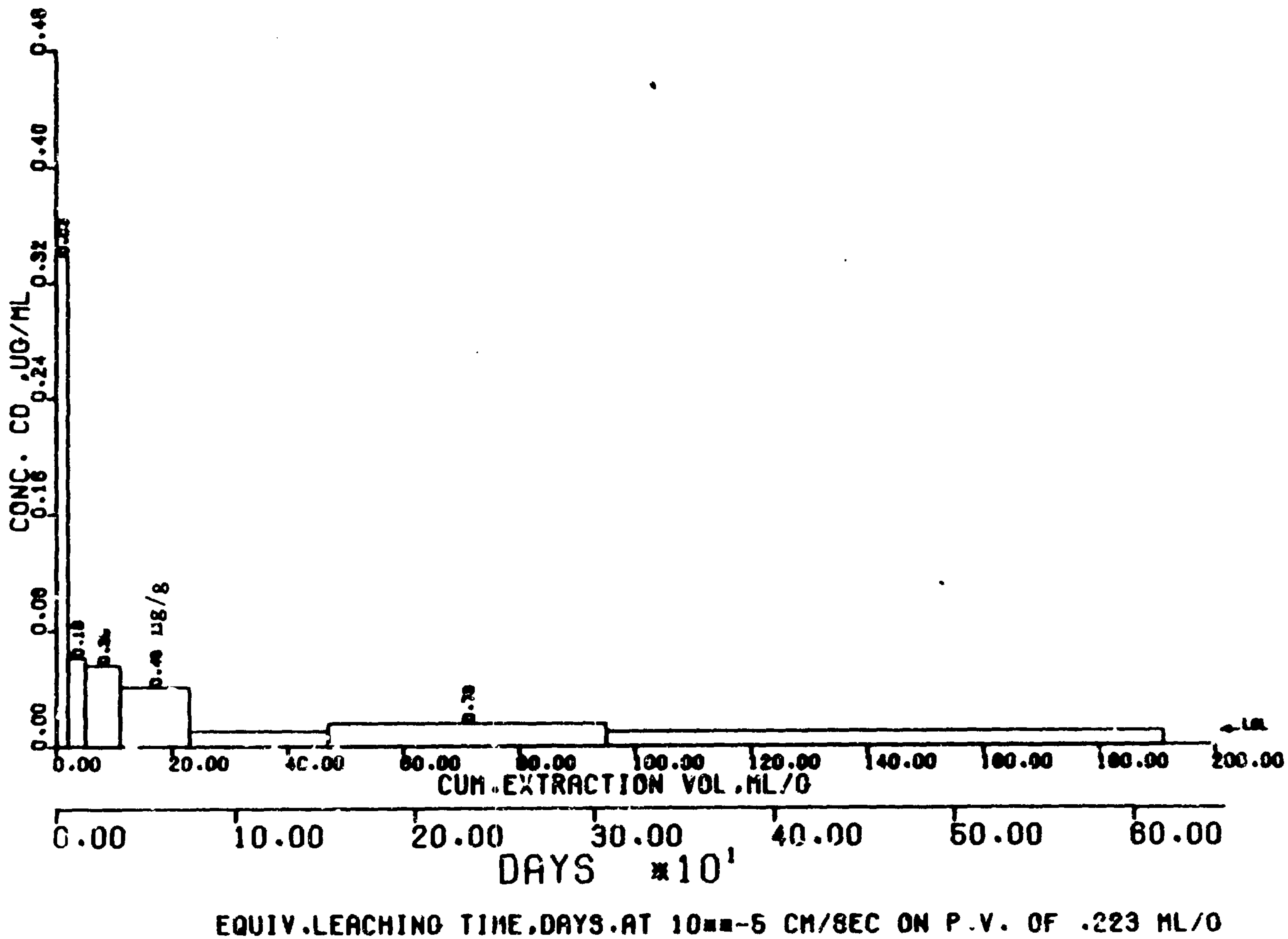


FIGURE 98. EXTRACTION OF CADMIUM FROM ZINC SECONDARY-REFINING CINDERS.

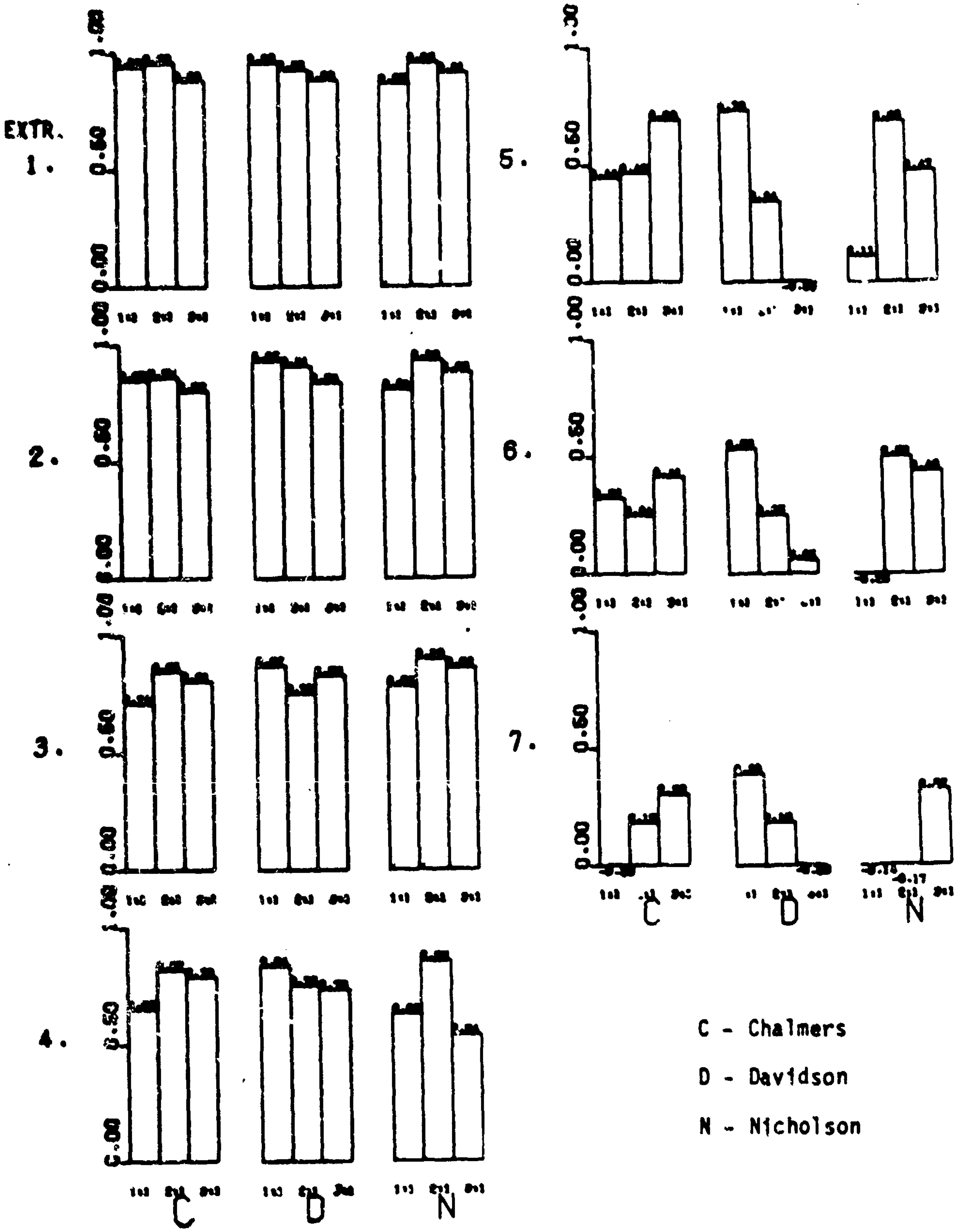


FIGURE 99. COMPARING FRACTION CADMIUM RETAINED BY SOILS FROM ZINC SECONDARY-REFINING CINDERS LEACHATE.

TABLE 50. CADMIUM FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	P'NETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.34	.60										
	I	.02	.04	.64	.60	.64	.94	.94	.06	28.13	87.96	15.75	86.37
	II	.02	.03	.01	.04	.01	.25	.25	.75	16.83	86.60	.33	18.43
	III	.04	.00	-.05	.63	-.05	-1.67	-1.67	2.67	5.56	79.81	-.63	-32.01
	I+II			.32	.34	.32	.96	.96	.04	87.34	89.34	21.33	87.32
	I+II+III			.20	.23	.28	.00	.00	.12	63.87	89.09	7.38	82.20
2	W	.06	.18										
	I	.03	.09	.09	.06	.73	.50	.05	.50	13.50	85.76	8.00	82.00
	II	.03	.09	.00	.13	.01	.00	.00	1.00	5.61	79.90	.11	6.34
	III	.03	.09	.00	.12	-.05	.00	-.42	1.00	4.94	78.57	-.56	-29.05
	I+II			.05	.43	.37	.50	.06	.50	30.11	88.10	8.11	82.97
	I+II+III			.03	.29	.23	.50	.00	.50	57.06	89.00	7.56	82.4
3	W	.06	.33										
	I	.04	.21	.12	1.19	.05	.36	.71	.64	6.36	81.06	4.00	75.96
	II	< .01	<.06	.15	.34	.16	.71	.47	.29	10.92	84.77	2.67	69.44
	III	< .01	<.06	.00	.10	-.05	.00	-.20	1.00	7.42	82.32	-.03	-39.81
	I+II			.14	.60	.51	.02	.05	.10	49.67	88.85	16.67	86.57
	I+II+III			.09	.40	.32	.02	.01	.10	98.09	89.36	15.83	86.39
4	W	.04	.48										
	I	.02	.24	.24	1.60	1.09	.50	.65	.50	6.54	81.34	4.50	77.47
	II	<.01	<.12	.12	.59	.20	.50	.40	.50	6.46	81.20	2.33	66.80
	III	<.01	<.12	.00	.33	-.05	.00	-.17	1.00	3.71	74.91	-.42	-22.62
	I+II			.10	.84	.69	.75	.82	.25	27.83	87.94	11.33	84.96
	I+II+III			.12	.56	.44	.75	.79	.25	40.05	88.81	10.92	84.77
5	W	< .01	<.24										
	I	.02	.40	-.24	1.92	.05	-1.00	.44	2.00	2.70	70.22	1.75	60.26
	II	.03	.73	-.24	1.07	.04	-.50	.04	1.50	.74	36.62	.06	3.18
	III	<.01	<.24	.40	1.03	.43	.67	.42	.33	3.05	75.46	1.79	60.83
	I+II			-.24	.96	.44	-2.00	.46	3.00	3.97	75.87	1.22	50.71
	I+II+III			.00	.64	.44	.00	.69	1.00	24.02	87.62	5.46	79.62
6	W	.02	.73										
	I	.02	.73	.00	2.65	.05	.00	.32	1.00	1.05	61.66	1.17	49.40
	II	.02	.97	-.24	1.00	-.20	-.33	-.11	1.33	.31	17.08	-.21	-11.77
	III	.02	.97	.00	2.00	.43	.00	.22	1.00	.96	43.94	.45	24.13
	I+II			-.12	1.32	.32	-.33	.24	1.33	2.73	69.88	.67	33.69
	I+II+III			-.08	.88	.36	-.33	.41	1.33	5.76	80.14	1.11	48.10
7	W	<.01	<.97										
	I	.03	2.91	-1.94	3.62	-1.09	-2.00	-.30	3.00	-.20	-11.48	-.38	-20.56
	II	<.01	<.97	1.94	4.71	1.74	.67	.37	.33	2.31	66.57	1.79	60.83
	III	<.01	<.97	.00	2.97	.43	.00	.15	1.00	.96	43.94	.45	24.13
	I+II			.00	1.01	.32	.00	.18	1.00	2.73	69.88	.67	33.69
	I+II+III			.00	1.21	.36	.00	.30	1.00	5.76	80.14	1.11	48.10

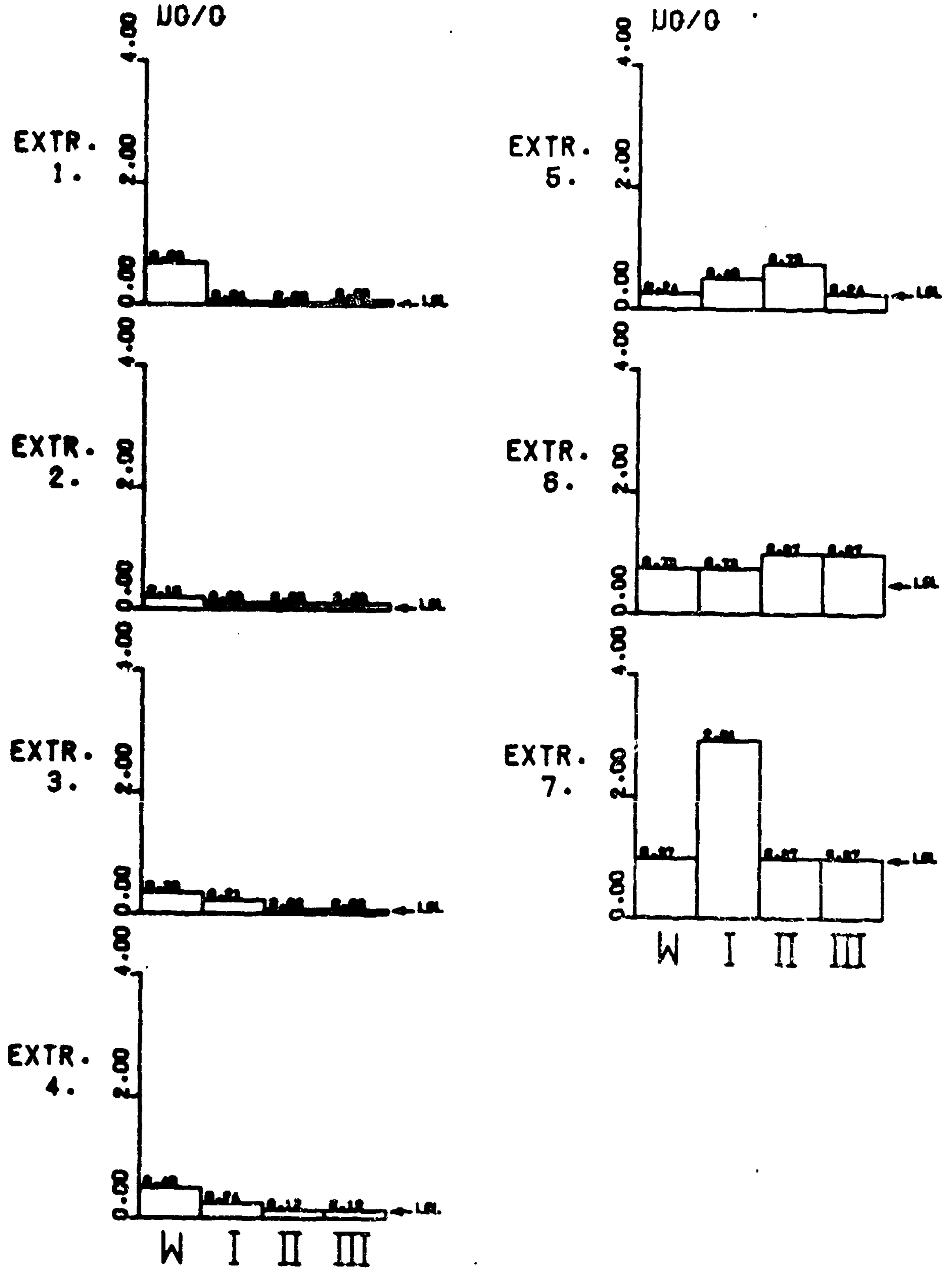


FIGURE 100. WEIGHT OF CADMIUM FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

TABLE 51. CADMIUM FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.34	.60										
	I	.02	.03	.45	.60	.45	.96	.96	.04	69.19	89.17	21.33	87.32
	II	.03	.05	-.02	.03	-.02	-.67	-.67	1.67	28.31	87.98	-.40	-21.80
	III	.04	.08	-.03	.05	-.03	-.60	-.60	1.60	17.57	86.74	-.37	-20.56
	I+II			.31	[illegible]	[illegible]	.93	.93	.07	177.25	89.55	12.40	85.37
	I+II+III			.28	[illegible]	[illegible]	.88	.88	.12	[illegible]	89.66	7.30	92.20
2	W	.06	.10										
	I	<.01	<.03	.15	.18	.14	.83	.83	.17	74.19	89.23	26.33	87.83
	II	<.01	<.03	.00	.06	-.02	.00	-.33	1.33	47.19	88.79	-.67	-33.69
	III	.02	.06	-.03	.08	-.06	-1.00	-.75	2.00	22.93	87.50	-1.00	-45.00
	I+II			.08	.43	.39	.83	.91	.17	217.89	89.74	25.67	87.77
	I+II+III			.04	.29	.20	.67	.84	.33	227.10	89.75	11.83	85.17
3	W	.06	.23										
	I	.02	.09	.28	1.17	1.00	.73	.85	.27	77.62	87.91	11.64	85.01
	II	.04	.21	-.12	.35	-.14	-1.33	-.93	2.33	[illegible]	88.74	-.67	-33.69
	III	<.01	<.06	.15	.29	.09	.71	.31	.29	[illegible]	[illegible]	1.50	56.31
	I+II			.06	.43	.46	.36	.75	.64	[illegible]	[illegible]	4.28	76.72
	I+II+III			.09	.48	.32	.32	.83	.18	[illegible]	[illegible]	16.33	86.50
4	W	.04	.08										
	I	<.01	<.12	.31	1.60	1.46	.75	.84	[illegible]	[illegible]	87.57	11.59	85.07
	II	<.01	<.12	.08	.27	-.14	.00	-.52	1.00	[illegible]	[illegible]	[illegible]	-49.49
	III	.02	.09	-.12	.41	-.33	-1.00	-.87	2.00	[illegible]	[illegible]	[illegible]	[illegible]
	I+II			.19	.84	.63	.75	.75	.25	56.27	89.52	13.42	84.52
	I+II+III			.09	.56	.41	.50	.73	.50	58.92	89.03	5.70	79.87
5	W	<.01	<.24										
	I	<.21	<.24	.00	1.92	1.40	.60	.73	1.00	11.77	85.15	5.79	80.20
	II	.04	.05	-.31	.52	-.75	-2.50	-1.45	3.50	.83	39.63	-.88	-41.30
	III	.07	1.02	-.73	1.26	-.73	-.86	-.60	1.86	.44	23.73	-.48	-25.68
	I+II			-.30	.96	.33	-2.50	.34	3.50	7.61	82.51	.77	37.73
	I+II+III			-.44	.64	-.03	-5.50	-.60	6.50	8.72	83.06	-.06	-3.67
6	W	.02	.73										
	I	.02	.73	.00	2.43	1.40	.00	.53	1.00	3.92	75.70	1.93	62.62
	II	.02	.73	.03	1.24	-.75	.03	-.60	1.00	.97	44.03	-1.03	-45.78
	III	<.01	<.40	.24	1.99	-.52	.33	-.26	.67	1.93	62.57	-1.06	-46.74
	I+II			.03	1.22	.33	.00	.25	1.00	0.00	33.50	.93	42.98
	I+II+III			.30	.30	.05	.33	.05	.67	27.21	87.90	.29	16.25
7	W	<.01	<.97										
	I	<.01	<.97	.00	3.62	1.40	.00	.39	1.00	2.94	71.20	1.45	55.37
	II	<.01	<.97	.00	2.21	-.75	.00	-.34	1.00	.72	35.93	-.77	-37.63
	III	.03	2.91	-1.94	2.96	-2.45	-2.00	-.83	3.00	-.35	-19.05	-.84	-40.16
	I+II			.00	1.91	.33	.00	.18	1.00	6.66	81.46	.60	34.10
	I+II+III			-.65	1.21	-.60	-2.06	-.58	3.00	3.87	75.51	-.62	-31.72

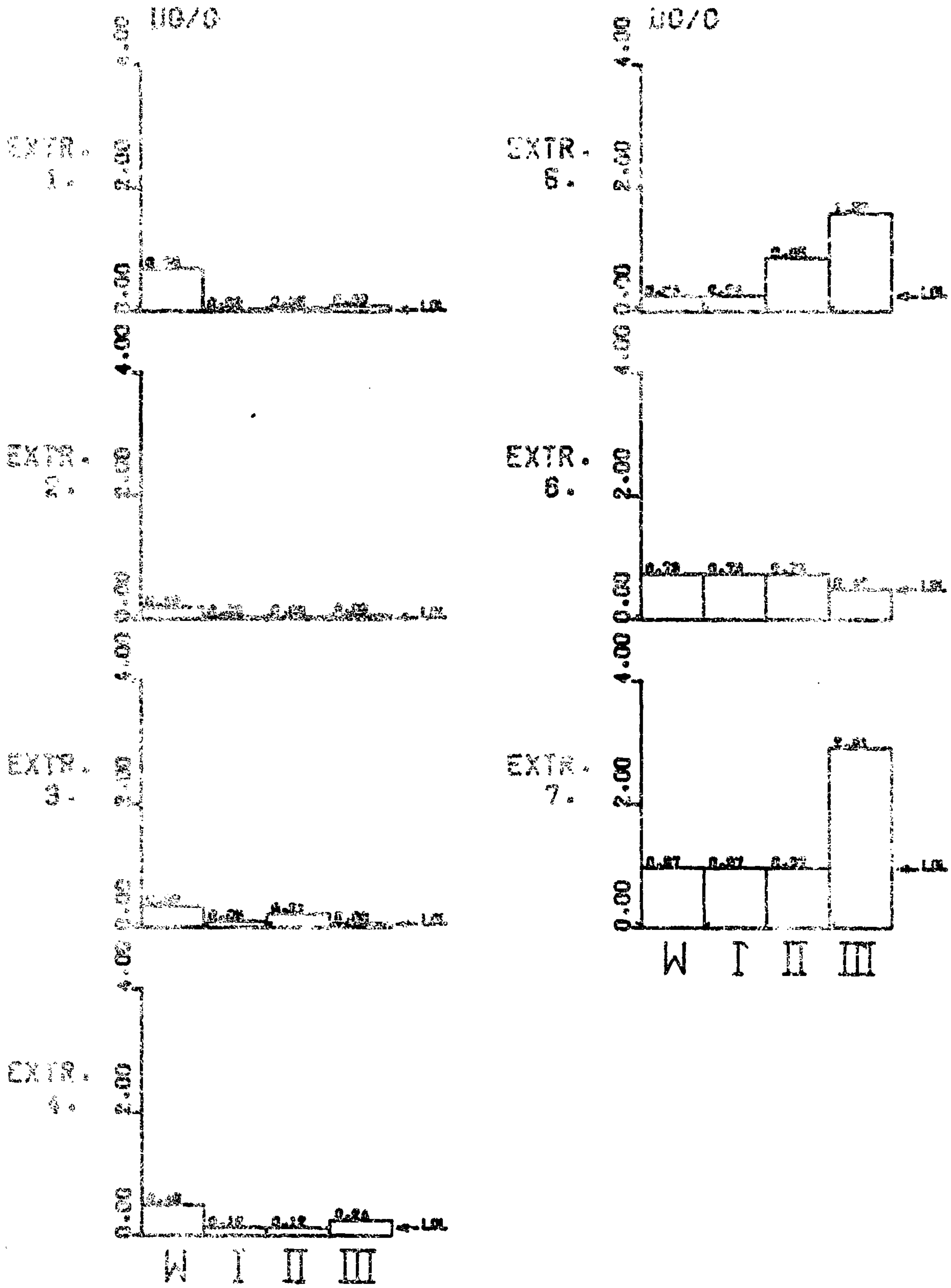


FIGURE 101. WEIGHT OF CADMIUM FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

TABLE 52. CADMIUM FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

EXP. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.34	.60										
	I	.05	.09	.59	.60	.59	.87	.87	.13	11.94	85.21	6.44	81.18
	II	.02	.03	.06	.09	.06	.67	.67	.33	18.50	86.91	2.00	63.43
	III	.03	.06	-.03	.03	-.03	-1.00	-1.00	2.00	7.75	82.65	-.50	-26.57
	I+II			.32	.34	.32	.96	.96	.04	87.34	89.34	21.33	87.32
	I+II+III			.21	.23	.21	.91	.91	.09	84.42	89.32	10.17	84.38
2	W	.06	.10										
	I	.03	.08	.11	.86	.69	.58	.81	.42	15.73	86.36	9.13	83.75
	II	<.01	<.03	.05	.17	.11	.60	.64	.40	20.00	87.14	3.50	74.05
	III	.02	.05	-.02	.06	-.05	-.50	-.75	1.50	10.00	84.29	-1.00	-45.00
	I+II			.00	.43	.40	.83	.93	.17	92.34	89.38	26.33	87.83
	I+II+III			.05	.29	.25	.75	.80	.25	115.57	89.50	16.56	86.54
3	W	.06	.33										
	I	.02	.09	.24	1.19	.93	.73	.78	.27	15.73	86.37	10.28	84.44
	II	<.01	<.06	.03	.26	.14	.33	.53	.67	10.50	34.56	2.25	66.04
	III	<.01	<.06	.00	.12	-.05	.00	-.38	1.00	7.50	82.41	-.75	-36.87
	I+II			.14	.60	.54	.82	.90	.18	50.67	88.87	17.67	86.76
	I+II+III			.09	.40	.34	.82	.86	.18	91.17	89.37	16.92	86.62
4	W	.04	.40										
	I	.03	.36	[illegible]	1.60	1.06	.25	.63	.75	4.20	76.84	2.90	70.79
	II	<.01	<.12	[illegible]	.62	.38	.67	.61	.33	7.25	82.15	3.13	72.26
	III	.05	.61	-.40	.24	-.53	-4.00	-2.19	5.00	-.05	-2.86	-.00	-41.19
	I+II			.16	.84	.72	.75	.86	.25	28.33	87.98	11.83	85.17
	I+II+III			-.04	.56	.30	-.25	.54	1.25	8.92	83.60	1.49	56.16
5	W	<.01	<.24										
	I	.05	1.09	-.05	1.92	.21	-3.50	.11	4.50	.65	32.95	.19	10.75
	II	.02	.36	.73	1.71	1.11	.67	.65	.33	4.42	77.24	3.04	71.80
	III	<.01	<.24	.12	.61	-.41	.33	-.67	.67	.38	20.57	-1.69	-59.35
	I+II			-.06	.96	.66	-.50	.68	1.50	9.11	83.74	3.61	74.52
	I+II+III			.00	.64	.30	.00	.47	1.00	22.29	87.43	3.73	74.99
6	W	.02	.73										
	I	.03	1.45	-.73	2.65	-.52	-1.00	-.20	2.00	-.01	-.79	-.36	-19.68
	II	.02	.73	.73	3.17	1.83	.50	.58	.50	3.21	72.69	2.52	68.36
	III	<.01	<.40	.24	1.33	-.17	.33	-.12	.67	.69	34.51	-.34	-18.97
	I+II			.00	1.32	.66	.00	.50	1.00	4.56	77.62	1.81	61.02
	I+II+III			.08	.80	.38	.33	.43	.67	11.65	85.09	2.36	67.08
7	W	<.01	<.97										
	I	<.01	<.97	.00	3.62	-.52	.00	-.14	1.00	-.02	-1.19	-.54	-28.21
	II	.03	2.91	-1.94	4.14	-.11	-2.00	-.03	3.00	.14	7.71	-.04	-2.09
	III	<.01	<.97	1.94	4.24	1.77	.67	.42	.33	2.34	66.89	1.83	61.32
	I+II			-.97	1.81	-.31	-2.00	-.17	3.00	.47	25.28	-.22	-12.15
	I+II+III			.00	1.21	.38	.00	.32	1.00	5.82	80.26	1.18	49.77

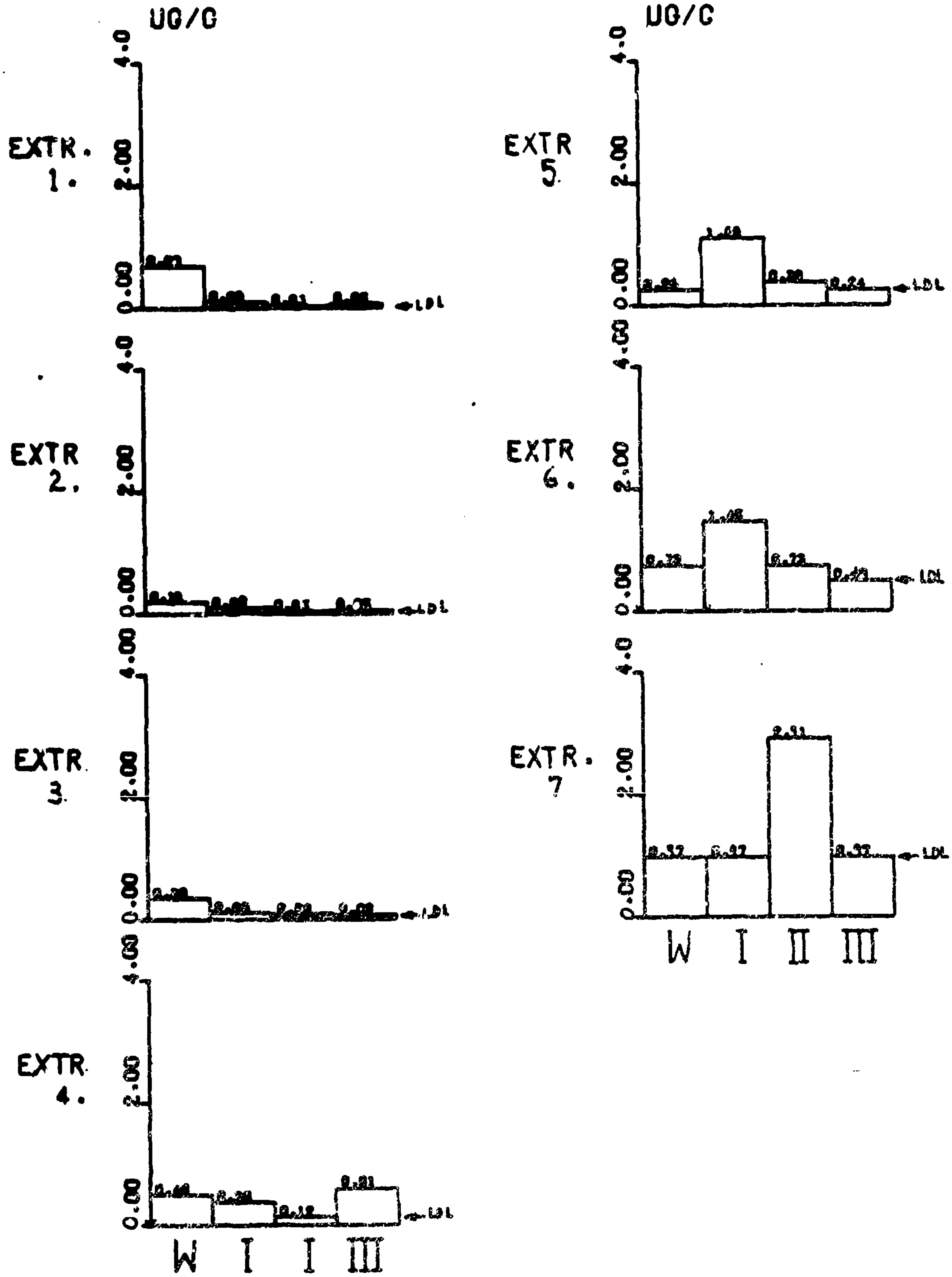


FIGURE 102. WEIGHT OF CADMIUM FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

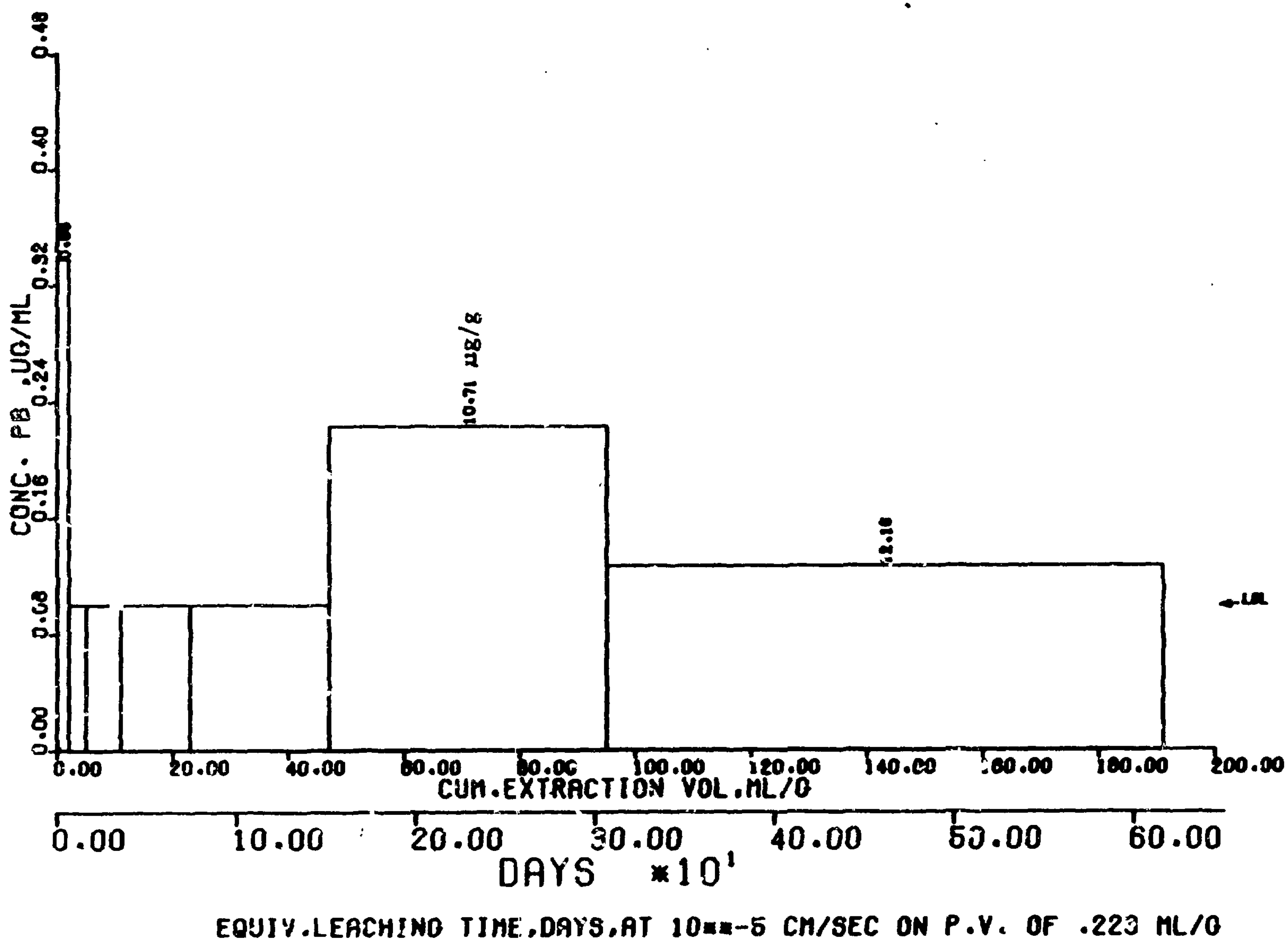


FIGURE 103. EXTRACTION OF LEAD FROM ZINC SECONDARY-REFINING CINDERS.

(Histograms were not prepared comparing fraction lead retained by soils from zinc secondary-refining cinder leachate because the concentration of lead in the soil extracts was below the detection limit.)

TABLE 53. LEAD FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.34	.68										
	I	<.10	<.20										
	II	<.10	<.20										
	III	<.10	<.20										
	I+II												
	I+II+III												
2	W	<.10	<.30										
	I	<.10	<.30										
	II	<.10	<.30										
	III	<.10	<.30										
	I+II												
	I+II+III												
3	W	<.10	<.60										
	I	<.10	<.60										
	II	<.10	<.60										
	III	.12	.75										
	I+II												
	I+II+III												
4	W	<.10	<1.20										
	I	<.10	<1.20										
	II	<.10	<1.20										
	III	.13	1.52										
	I+II												
	I+II+III												
5	W	<.10	<2.40										
	I	.12	2.87										
	II	.12	2.88										
	III	.29	6.96										
	I+II												
	I+II+III												
6	W	.22	10.71										
	I	.11	5.47										
	II	.19	9.19										
	III	<.10	<4.80										
	I+II												
	I+II+III												
7	W	.13	12.16										
	I	.18	17.64										
	II	.40	[illegible]										
	III	.25	24.07										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

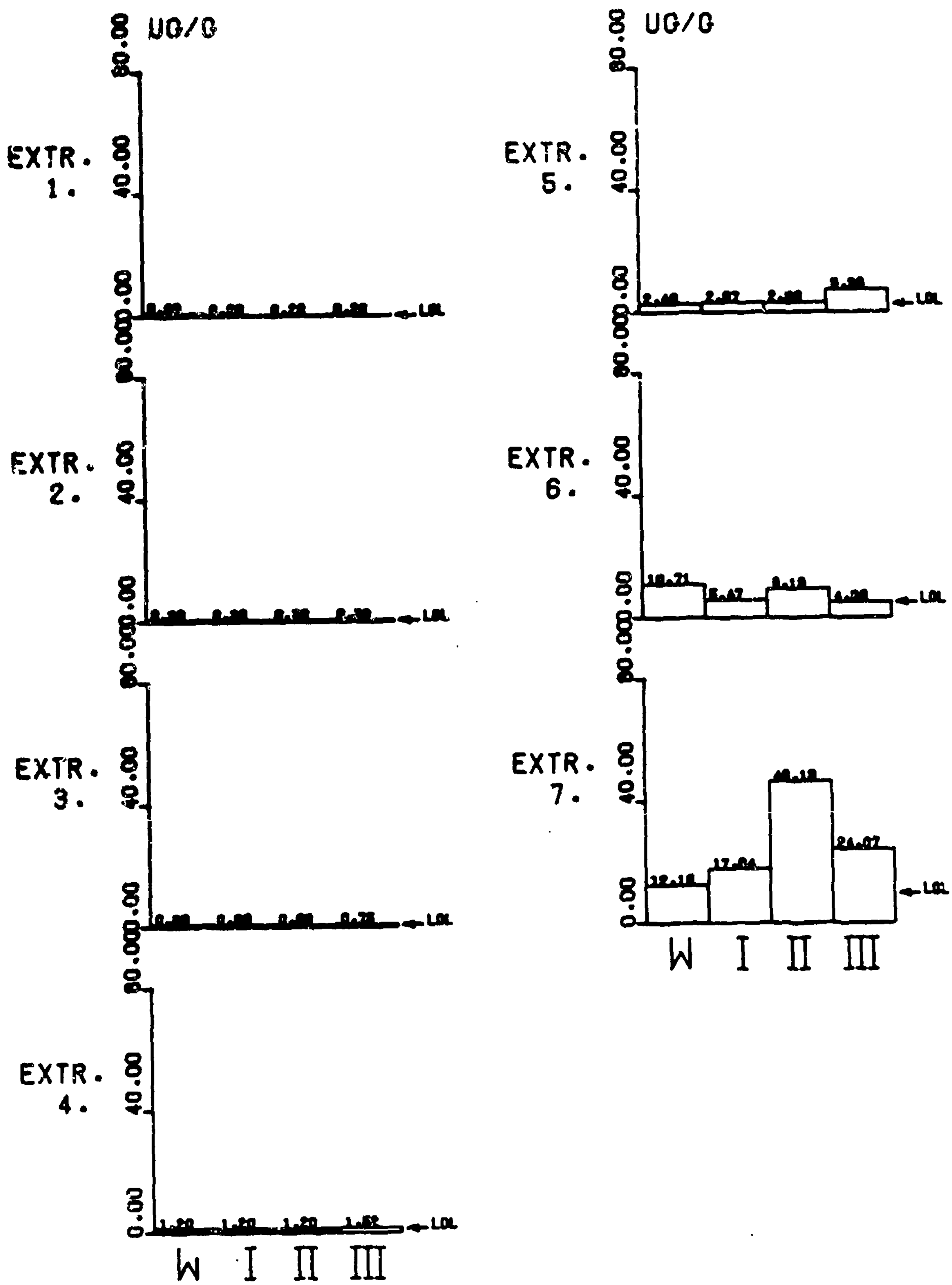


FIGURE 104. WEIGHT OF LEAD FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

TABLE 54. LEAD FROM ZINC SECONDA Y-REFINING CINDERS ON DAVIDSON SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.34	.68										
	I	<.10	<.20										
	II	<.10	<.20										
	III	<.10	<.20										
	I+II												
	I+II+III												
2	W	<.10	<.30										
	I	<.10	<.30										
	II	<.10	<.30										
	III	<.10	<.30										
	I+II												
	I+II+III												
3	W	<.10	<.60										
	I	<.10	<.60										
	II	<.10	<.60										
	III	<.10	<.60										
	I+II												
	I+II+III												
4	W	<.10	<1.20										
	I	<.10	<1.20										
	II	<.10	<1.20										
	III	.12	1.47										
	I+II												
	I+II+III												
	W	<.10	<2.40										
	I	<.10	<2.40										
	II	.12	2.81										
	III	.13	3.02										
	I+II												
	I+II+III												
6		.22	10.71										
	I	<.10	<4.90										
	II	<.10	<4.80										
	III	<.10	<4.80										
	I+II												
	I+II+III												
7	W	.13	12.16										
	I	<.10	<9.60										
	II	<.10	<9.60										
	III	<.10	<9.60										
	I+II												
	I+II+III												

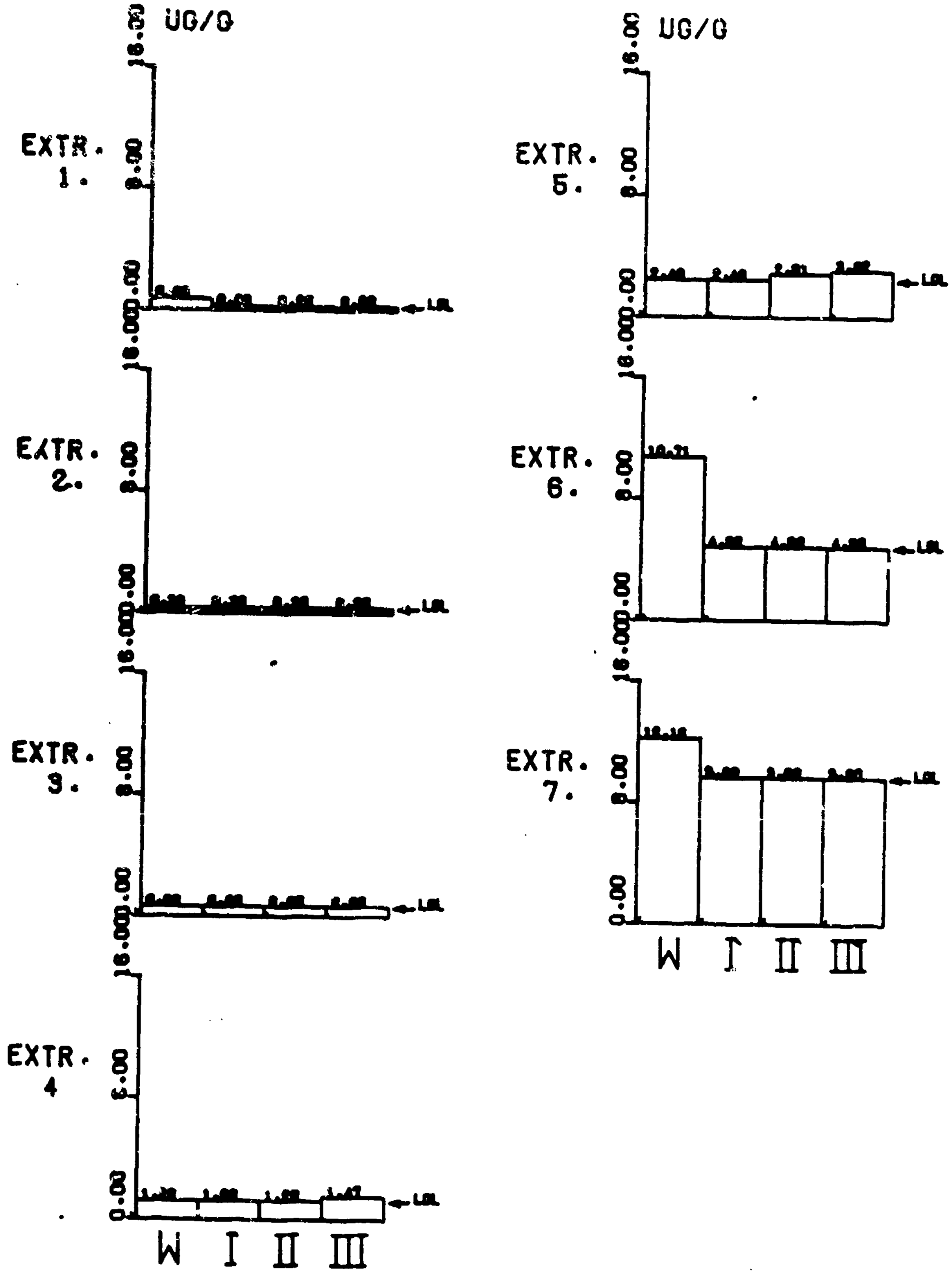


FIGURE 105. WEIGHT OF LEAD FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

TABLE 55. LEAD FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL. SOIL RATIO	INCL. SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.34	.68										
	I	<.10	<.20										
	II	<.10	<.20										
	III	<.10	<.20										
	I+II												
	I+II+III												
2	W	<.10	<.30										
	I	<.10	<.30										
	II	<.10	<.30										
	III	<.10	<.30										
	I+II												
	I+II+III												
3	W	<.10	<.60										
	I	<.10	<.60										
	II	<.10	<.60										
	III	<.10	<.60										
	I+II												
	I+II+III												
4	W	<.10	<1.20										
	I	.12	1.40										
	II	<.10	<1.20										
	III	<.10	<1.20										
	I+II												
	I+II+III												
5	W	<.10	<2.40										
	I	<.10	<2.40										
	II	.33	7.80										
	III	.22	5.25										
	I+II												
	I+II+III												
6	W	.22	10.71										
	I	<.10	<4.80										
	II	.15	7.04										
	III	<.10	<4.80										
	I+II												
	I+II+III												
7	W	.13	12.16										
	I	.27	25.44										
	II	<.10	<9.60										
	III	.20	19.15										
	I+II												
	I+II+III												

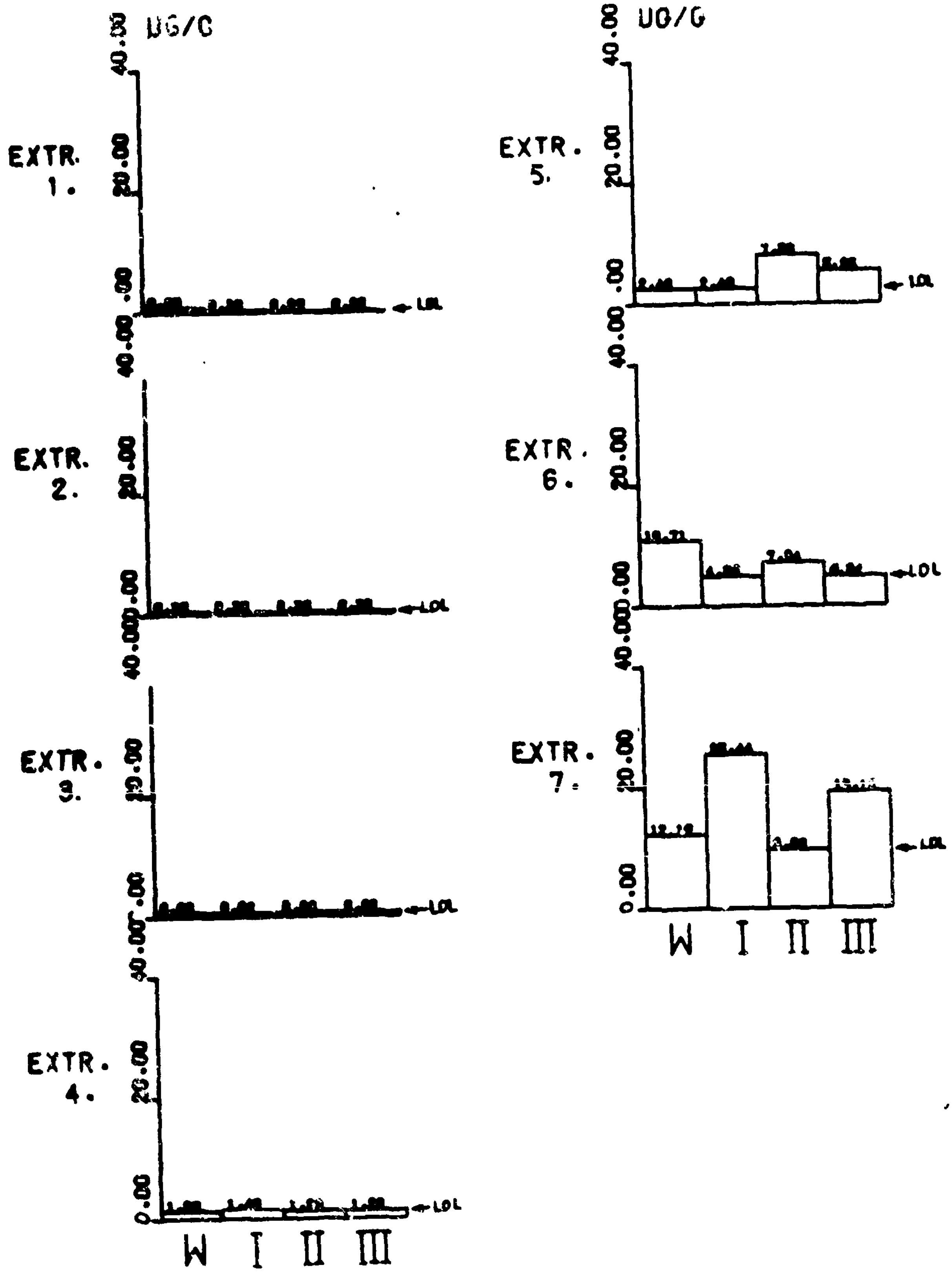


FIGURE 106. WEIGHT OF LEAD FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

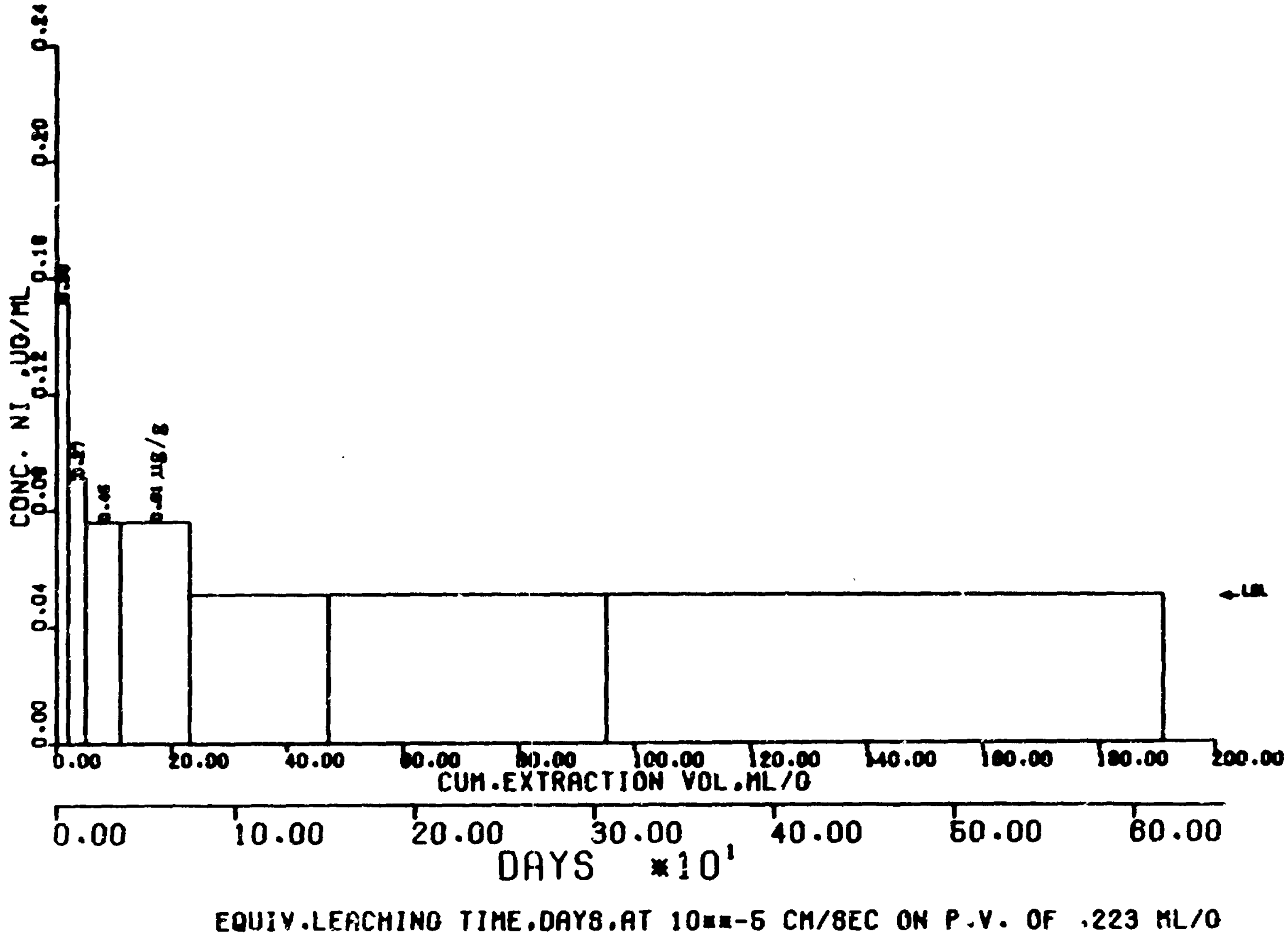


FIGURE 107. EXTRACTION OF NICKEL FROM ZINC SECONDARY-REFINING CINDERS.

(Histograms were not prepared comparing fraction nickel retained by soils from zinc secondary-refining cinder leachate because the concentration of nickel in the soil extracts was below the detection limit.)

TABLE [illegible]. NICKEL FROM ZINC SECONDARY REFINING CINDERS ON CHALMERS SOIL.

EXT. NO.	LAYER	CONCENTRATION UG/ML	CONCENTRATION UG/G	AMT. RETD. THIS EXT UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.15	.30										
	I	<.05	<.10										
	II	<.05	<.10										
	III	<.05	<.10										
	I+II												
	I+II+III												
2	W	.09	.27										
	I	<.05	<.15										
	II	<.05	<.15										
	III	<.05	<.15										
	I+II												
	I+II+III												
3	W	.08	.45										
	I	<.05	<.30										
	II	<.05	<.30										
	III	<.05	<.30										
	I+II												
	I+II+III												
4	W	.08	.91										
	I	<.05	<.61										
	II	<.05	<.61										
	III	<.05	<.61										
	I+II												
	I+II+III												
5	W	<.05	<1.21										
	I	<.05	<1.21										
	II	<.05	<1.21										
	III	<.05	<1.21										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

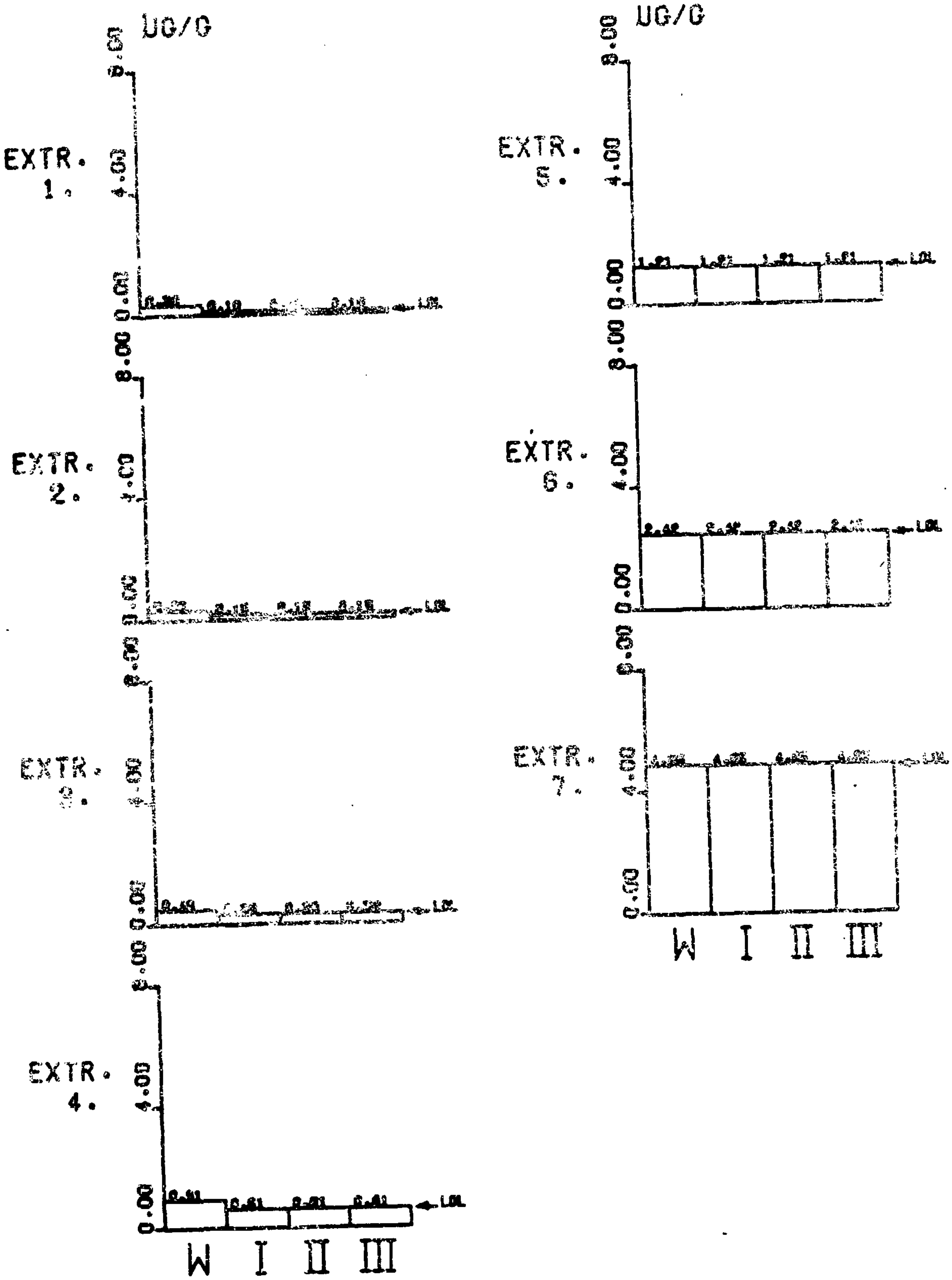


FIGURE 108. WEIGHT OF NICKEL FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

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TABLE 57. NICKEL FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.15	.34										
	I	<.05	<.10										
	II	<.05	<.10										
	III	<.05	<.10										
	I+II												
	I+II+III												
2	W	.09	.27										
	I	<.05	<.15										
	II	<.05	<.15										
	III	<.05	<.15										
	I+II												
	I+II+III												
3	W	.08	.45										
	I	<.05	<.30										
	II	<.05	<.30										
	III	<.05	<.30										
	I+II												
	I+II+III												
4	W	.08	.91										
	I	<.05	<.61										
	II	<.05	<.61										
	III	<.05	<.61										
	I+II												
	I+II+III												
5	W	<.05	<1.21										
	I	.07	1.73										
	II	<.05	<1.21										
	III	<.05	<1.21										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

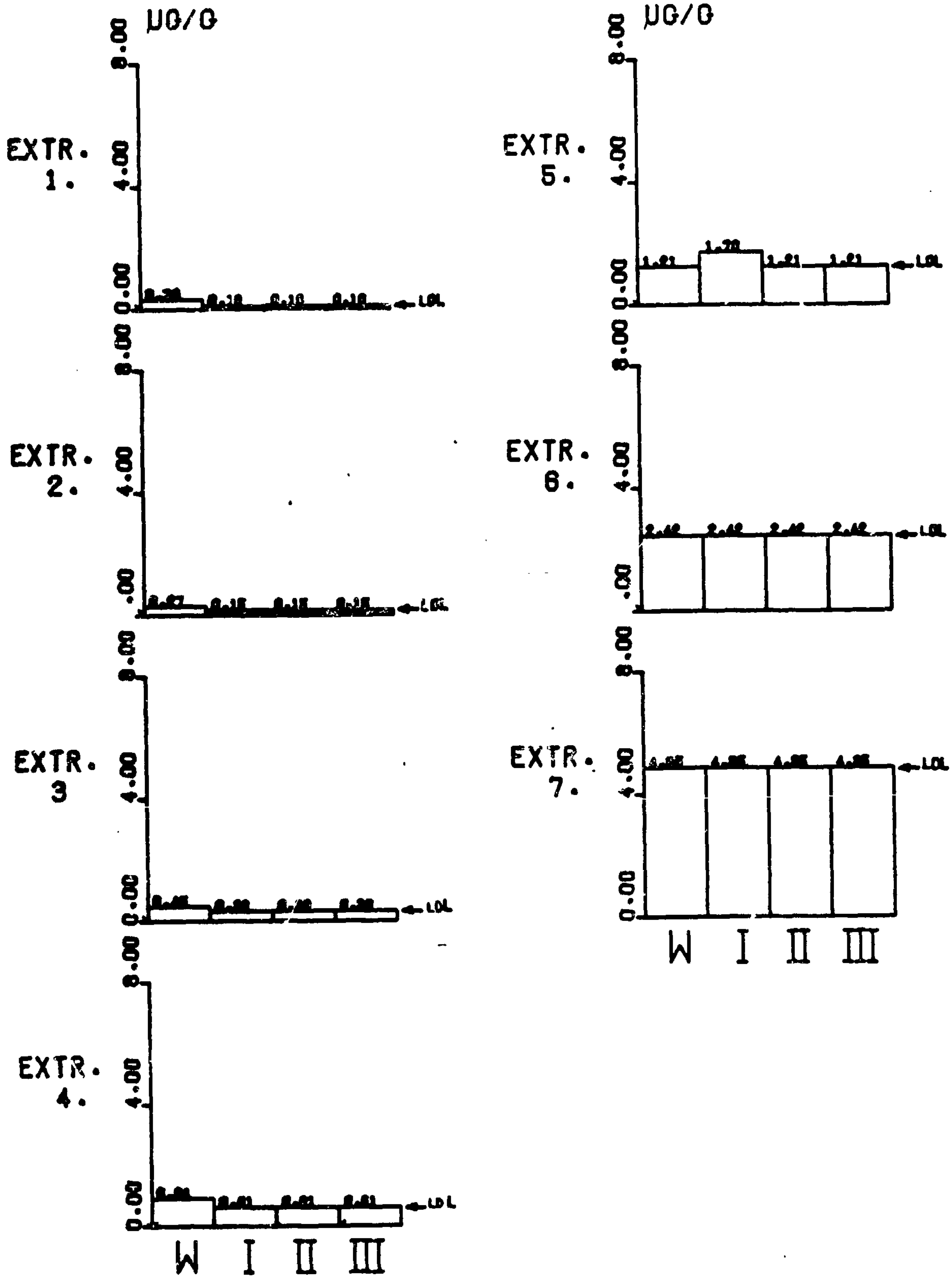


FIGURE 109. WEIGHT OF NICKEL FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

TABLE 58. NICKEL FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	.15	.30										
	I	<.05	<.10										
	II	<.05	<.10										
	III	<.05	<.10										
	I+II												
	I+II+III												
2	W	.09	.27										
	I	<.05	<.15										
	II	<.05	<.15										
	III	<.05	<.15										
	I+II												
	I+II+III												
3	W	.08	.45										
	I	<.05	<.30										
	II	<.05	<.30										
	III	<.05	<.30										
	I+II												
	I+II+III												
4	W	.08	.91										
	I	.06	.73										
	II	.10	1.15										
	III	<.05	<.61										
	I+II												
	I+II+III												
5	W	<.05	<1.21										
	I	.08	1.94										
	II	<.05	<1.21										
	III	.06	1.33										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

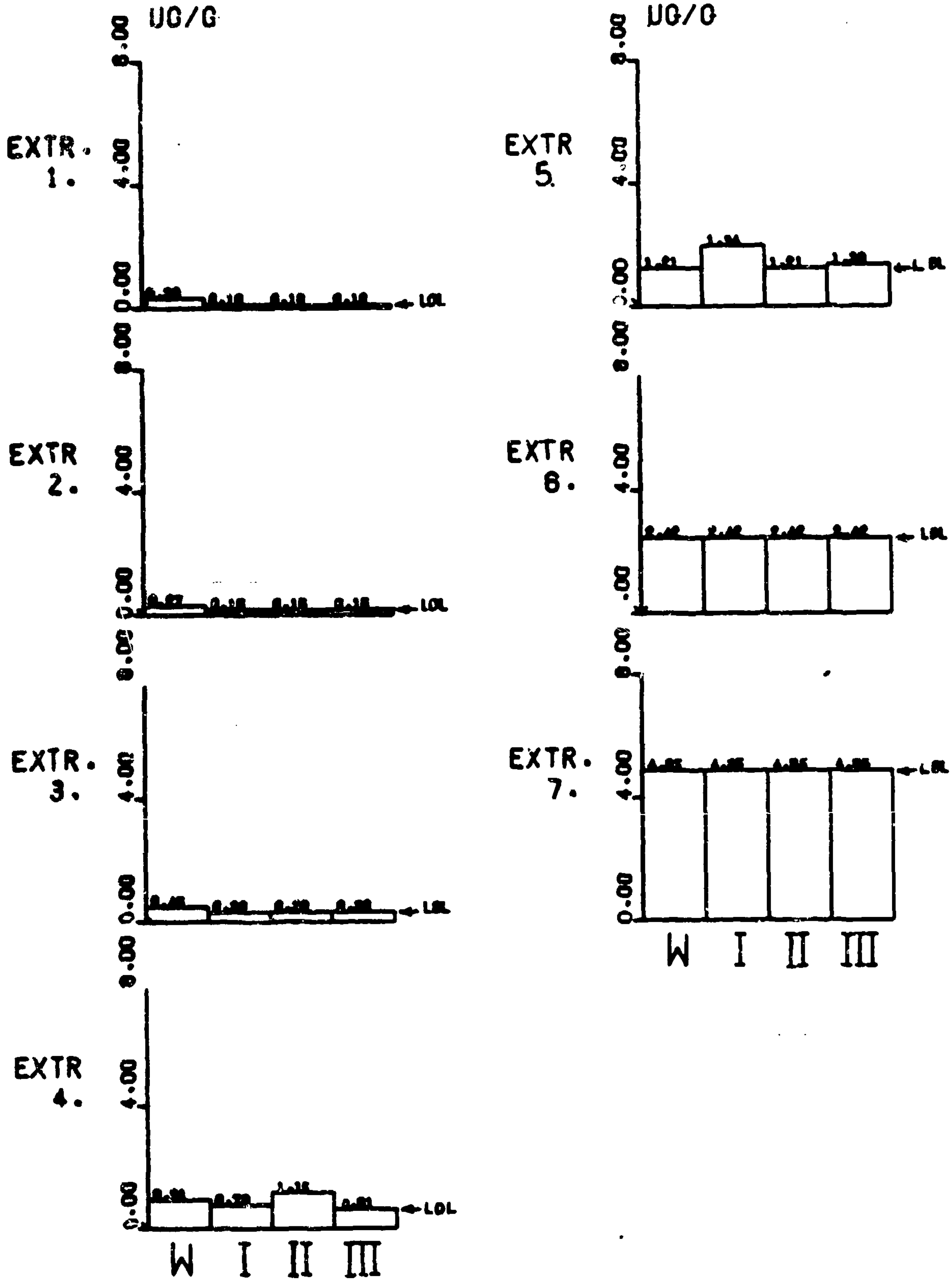


FIGURE 110. WEIGHT OF NICKEL FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

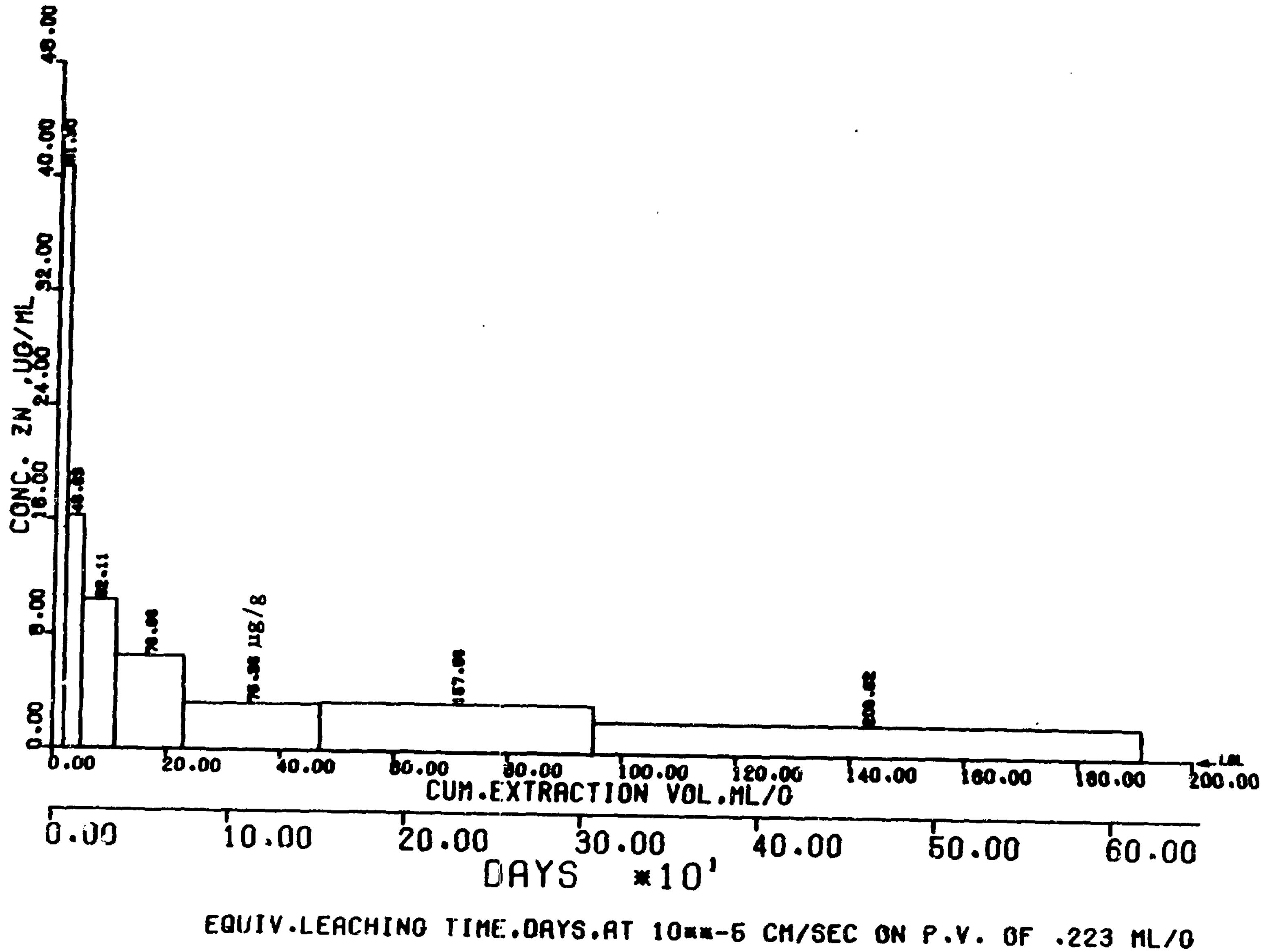


FIGURE 111. EXTRACTION OF ZINC FROM ZINC SECONDARY-REFINING CINDERS.

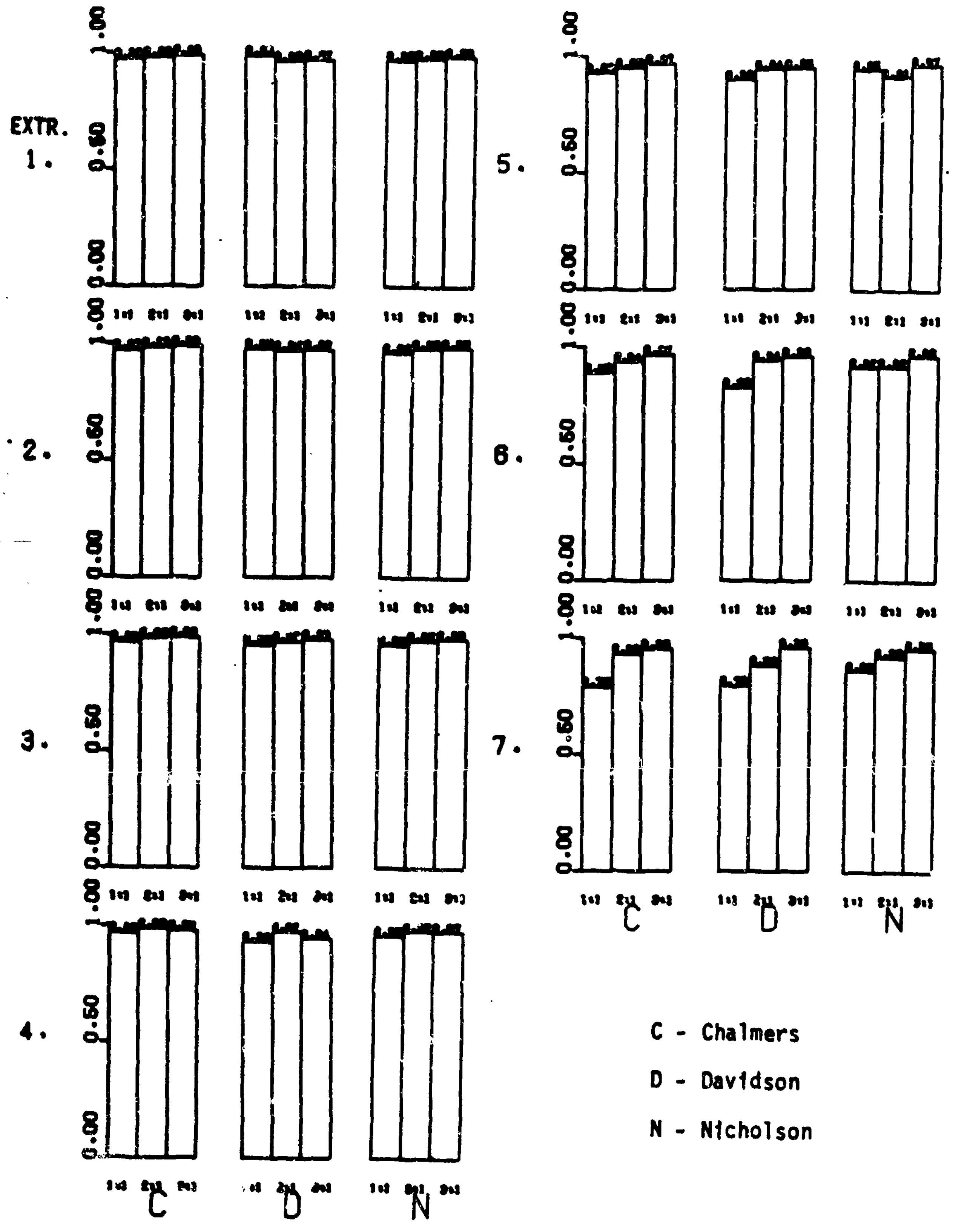


FIGURE 112. COMPARING FRACTION ZINC RETAINED BY SOILS FROM ZINC SECONDARY-REFINING CINDERS LEACHATE.

TABLE 59. ZINC FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	40.65	81.30										
	I	.99	1.98	79.33	81.30	79.33	.98	.98	.02	71.29	89.20	40.07	88.57
	II	.69	1.37	.61	1.98	.61	.31	.31	.69	45.43	88.74	.44	23.81
	III	.33	.67	.71	1.37	.71	.51	.51	.49	93.77	89.39	1.06	46.68
	I+II			39.97	40.65	39.97	.98	.98	.02	230.16	89.76	58.19	89.02
	I+II+III			26.88	27.10	26.88	.99	.99	.01	955.35	89.94	120.97	89.53
2	W	16.21	40.63										
	I	.40	1.44	47.19	129.94	126.52	.97	.97	.03	130.84	89.56	87.91	89.35
	II	.26	.77	.67	3.42	1.27	.46	.37	.54	81.63	89.30	1.65	58.74
	III	.20	.41	.17	2.15	.88	.22	.41	.78	103.42	89.45	1.44	55.25
	I+II			23.93	64.97	63.90	.98	.98	.02	405.33	89.88	165.39	89.65
	I+II+III			16.01	43.31	42.89	.99	.99	.01	1130.14	89.95	212.32	89.73
3	W	10.35	62.11										
	I	.41	2.48	59.63	192.05	186.15	.96	.97	.04	99.79	89.43	74.92	89.24
	II	.16	.94	1.55	5.90	2.82	.62	.48	.38	60.79	89.17	3.00	71.57
	III	.14	.85	.09	3.09	.96	.10	.31	.90	73.98	89.23	1.14	48.67
	I+II			30.59	96.03	94.48	.98	.98	.02	454.35	89.88	201.18	89.72
	I+II+III			20.42	64.02	63.31	.99	.99	.01	879.46	89.93	223.87	89.74
4	W	6.41	76.96										
	I	.30	3.58	73.39	269.01	259.53	.95	.96	.05	89.87	89.36	72.59	89.21
	II	.10	1.21	2.36	9.46	5.18	.66	.55	.34	55.27	88.96	4.28	76.83
	III	.38	4.55	-3.33	4.30	-2.37	-2.75	-.55	3.75	13.08	85.63	-.52	-27.52
	I+II			37.88	134.51	132.36	.98	.98	.02	422.37	89.86	218.41	89.74
	I+II+III			24.14	89.67	87.45	.94	.98	.06	180.10	89.68	57.72	89.01
5	W	3.18	76.36										
	I	.66	[illegible]	60.60	345.37	320.13	.79	.93	.21	24.24	87.64	28.32	87.18
	II	[illegible]	[illegible]	3.27	25.23	8.45	.21	.34	.79	5.63	79.92	.68	34.11
	III	.20	4.85	7.64	16.78	5.27	.61	.31	.39	13.83	85.87	1.09	47.37
	I+II			31.94	172.68	164.29	.84	.95	.16	46.12	88.76	26.32	87.82
	I+II+III			23.84	115.12	111.29	.94	.97	.06	183.59	89.69	68.86	89.17
6	W	3.20	157.56										
	I	.67	32.00	125.56	502.93	445.70	.80	.89	.20	15.86	86.39	13.93	85.89
	II	.31	15.03	16.97	57.23	25.42	.53	.44	.47	5.80	80.22	1.69	59.41
	III	.11	5.33	9.70	31.81	14.96	.65	.47	.35	14.39	86.03	2.81	70.38
	I+II			[illegible]	251.46	235.56	.90	.94	.10	47.80	88.80	31.35	88.17
	I+II+III			[illegible]	167.64	162.03	.97	.97	.03	195.45	89.71	91.15	89.37
7	W	2.12	203.62										
	I	.96	92.11	111.50	706.55	557.20	.55	.79	.45	6.72	81.54	6.05	80.61
	II	.17	16.40	75.63	149.34	101.05	.82	.68	.18	9.88	84.22	6.13	80.74
	III	.17	16.40	[illegible]	48.29	14.96	.00	.31	1.00	4.66	77.88	.91	42.23
	I+II			[illegible]	353.27	329.13	.92	.93	.08	54.93	88.96	39.93	88.57
	I+II+III			62.38	235.52	224.41	.92	.95	.08	74.59	89.23	40.84	88.60

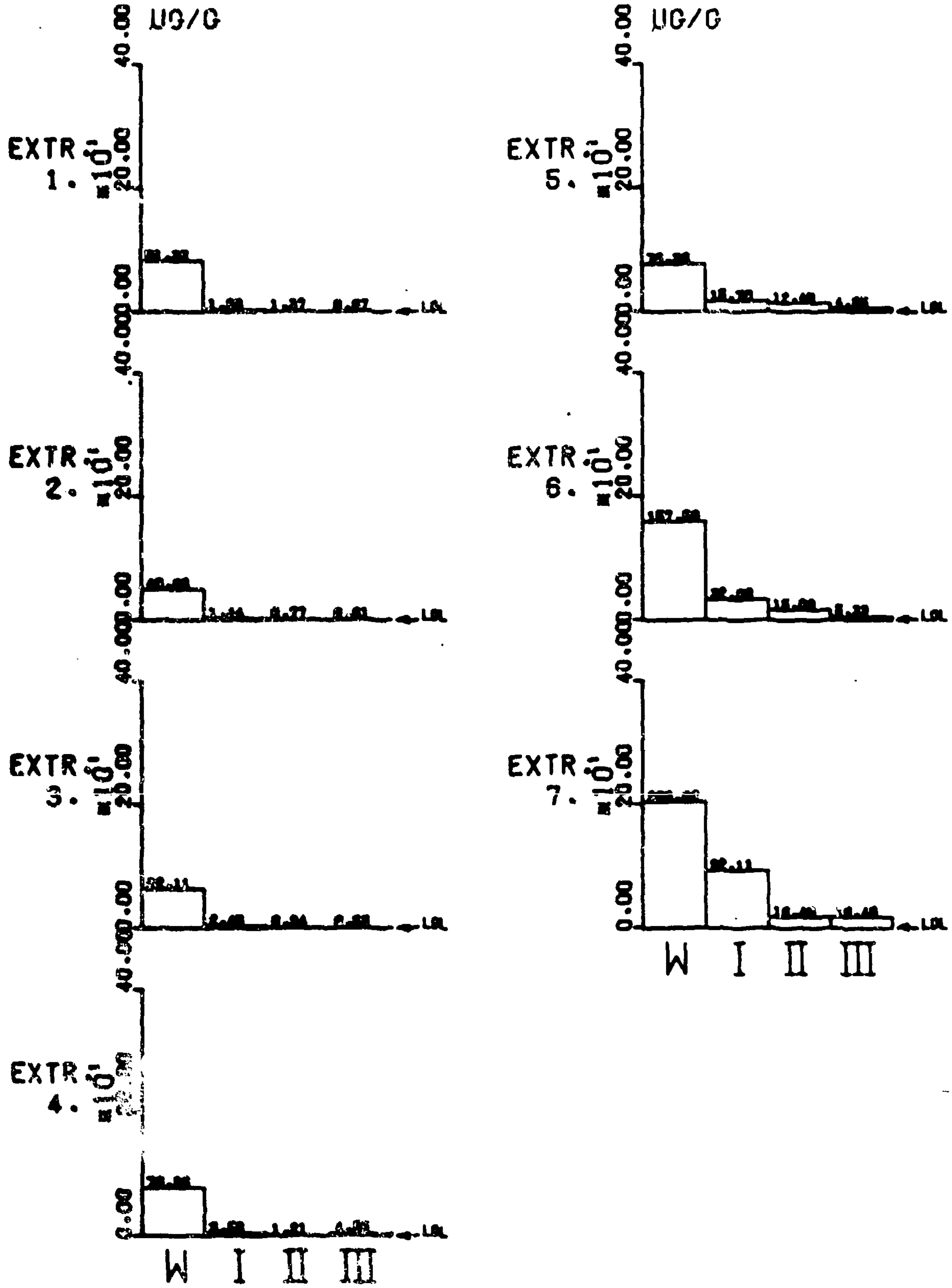


FIGURE 113. WEIGHT OF ZINC FROM ZINC SECONDARY-REFINING CINDERS ON CHALMERS SOIL.

TABLE 60. ZINC FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	40.65	81.30										
	I	.45	.91	80.40	81.30	80.40	.99	.99	.01	140.95	89.62	88.44	89.35
	II	1.43	2.87	-1.96	.91	-1.96	-2.16	-2.16	3.16	18.49	86.90	-.68	-34.34
	III	1.20	2.40	.46	2.87	.46	.16	.16	.84	23.07	87.52	.19	10.94
	I+II			39.22	40.65	39.22	.96	.96	.04	104.04	89.45	27.35	87.91
	I+II+III			26.30	27.10	26.30	.97	.97	.03	230.75	89.76	32.82	88.25
2	W	16.21	40.63										
	I	.66	1.50	46.65	129.94	127.04	.96	.98	.04	91.73	89.38	64.01	89.11
	II	.33	.90	1.00	2.89	-.96	.50	-.33	.50	54.80	88.96	-.97	-44.26
	III	.38	1.14	-.15	3.05	.31	-.15	.00	1.15	40.60	88.82	.28	15.41
	I+II			23.02	64.97	63.04	.98	.97	.02	351.44	89.84	128.04	89.55
	I+II+III			15.83	43.31	42.13	.98	.97	.02	546.80	89.90	111.24	89.48
3	W	18.35	62.11										
	I	.94	5.64	56.40	192.05	183.52	.91	.96	.09	42.32	88.65	32.56	88.24
	II	.36	2.15	3.40	8.53	2.52	.62	.30	.38	26.74	87.86	1.17	49.57
	III	.12	.73	1.42	6.00	1.74	.66	.29	.34	78.02	89.27	2.39	67.29
	I+II			29.90	96.03	93.02	.97	.97	.03	180.74	89.70	86.48	89.34
	I+II+III			20.46	64.02	62.59	.99	.98	.01	930.92	89.94	258.23	89.78
4	W	6.41	76.96										
	I	.88	10.60	66.36	269.01	249.88	.86	.93	.14	28.75	88.01	23.56	87.57
	II	.14	1.70	8.91	19.13	11.43	.84	.60	.16	39.15	88.54	6.74	81.56
	III	.97	11.70	-10.00	7.70	-8.26	-5.07	-1.07	6.07	4.00	75.95	-.71	-35.24
	I+II			37.63	134.51	130.66	.98	.97	.02	283.66	89.80	154.00	89.63
	I+II+III			21.76	89.67	84.35	.85	.94	.15	63.96	89.10	21.64	87.35
5	W	3.10	76.36										
	I	.60	16.20	60.12	345.37	309.99	.79	.90	.21	22.47	87.45	19.09	87.00
	II	.48	11.44	4.61	35.38	16.04	.28	.45	.72	6.11	80.70	1.38	54.04
	III	.10	2.30	9.33	19.34	1.07	.80	.06	.20	24.35	87.65	.46	24.93
	I+II			32.36	172.60	163.02	.85	.94	.15	46.93	88.78	28.02	87.96
	I+II+III			24.60	115.12	109.03	.97	.95	.03	357.00	89.84	142.05	89.60
6	W	3.20	157.56										
	I	1.11	53.33	104.23	582.93	414.23	.65	.82	.34	8.80	83.52	7.77	82.66
	II	.22	10.42	42.90	80.70	58.94	.80	.66	.20	10.93	84.77	5.66	79.97
	III	.07	3.39	7.03	29.76	8.10	.67	.27	.33	18.59	86.92	2.39	67.27
	I+II			73.57	251.46	236.58	.93	.94	.07	66.50	87.14	45.48	88.74
	I+II+III			51.39	167.54	160.42	.98	.96	.02	287.68	87.08	141.82	89.60
7	W	2.12	203.62										
	I	.60	57.21	146.41	786.55	560.64	.72	.79	.28	10.76	84.69	9.86	84.17
	II	.58	55.27	1.94	145.91	60.88	.03	.42	.97	2.10	64.50	1.10	47.77
	III	.10	9.21	46.06	85.03	54.15	.83	.64	.17	11.85	85.18	5.88	80.35
	I+II			74.17	353.27	310.76	.73	.88	.27	15.23	86.24	11.25	84.92
	I+II+III			64.80	235.52	225.22	.95	.96	.05	127.09	89.55	73.35	89.22

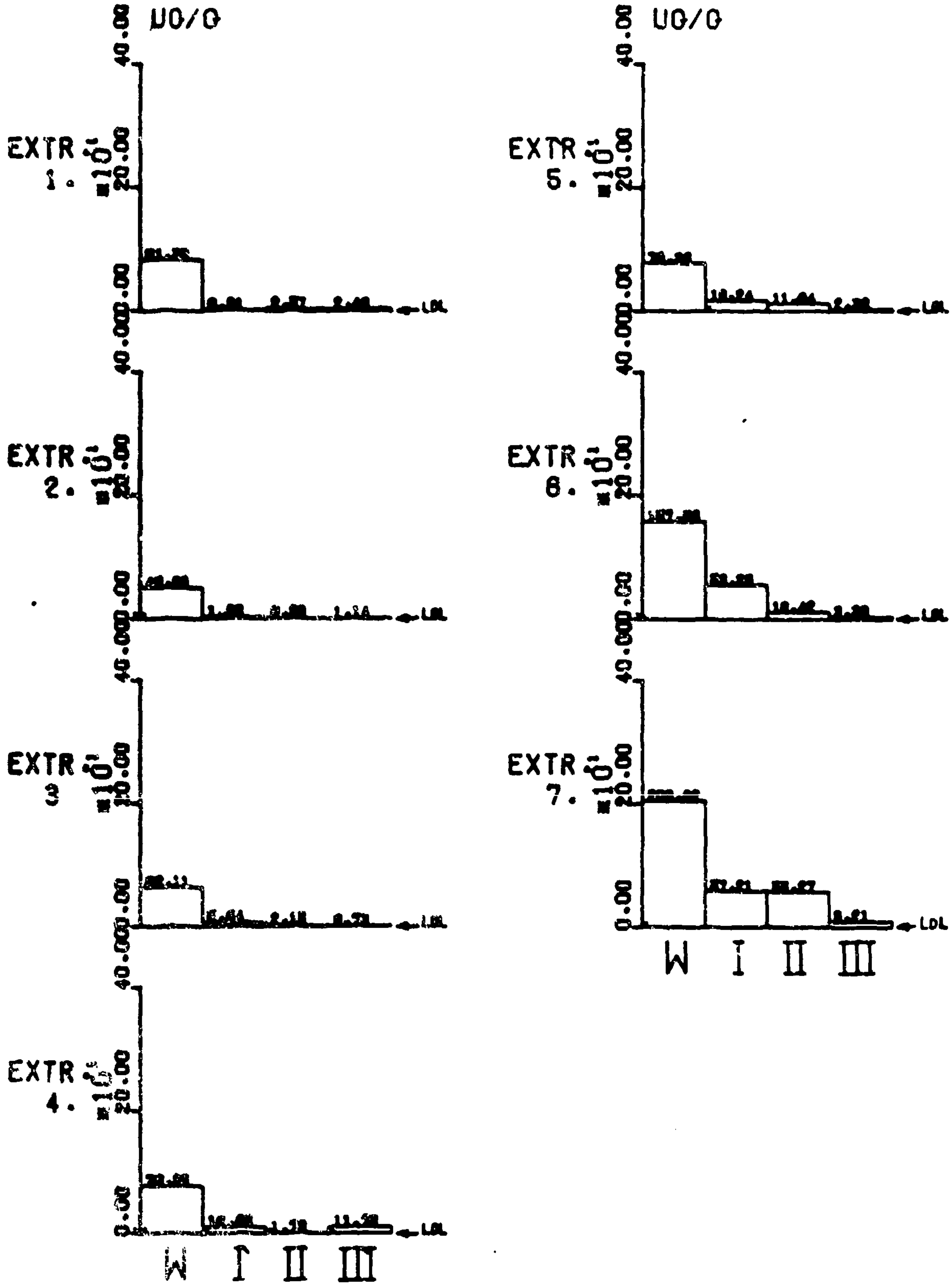


FIGURE 114. WEIGHT OF ZINC FROM ZINC SECONDARY-REFINING CINDERS ON DAVIDSON SOIL.

TABLE 61. ZINC FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	40.65	81.30										
	I	1.19	2.30	70.92	81.30	70.92	.97	.97	.03	64.49	89.11	33.11	88.27
	II	.05	1.70	.69	2.30	.69	.29	.29	.71	44.49	88.71	.40	22.04
	III	.50	1.00	.70	1.70	.70	.41	.41	.59	75.50	89.24	.70	34.88
	I+II			39.00	40.65	39.00	.98	.98	.02	223.25	89.74	46.92	88.78
	I+II+III			26.77	27.10	26.77	.99	.99	.01	753.58	89.92	80.31	89.29
2	W	16.21	40.63										
	I	.04	2.51	46.12	129.94	125.04	.95	.96	.05	79.46	89.28	49.72	88.85
	II	.23	.60	1.03	4.90	2.52	.73	.51	.27	113.41	89.49	3.70	74.86
	III	.36	1.09	-.41	2.30	.29	-.60	.12	1.60	68.84	89.17	.26	14.78
	I+II			23.97	64.97	63.70	.99	.98	.01	625.97	89.91	187.10	89.69
	I+II+III			15.05	43.31	42.62	.98	.98	.02	734.37	89.92	117.20	89.51
3	W	10.35	62.11										
	I	.62	3.73	58.39	192.05	183.43	.94	.96	.06	69.29	89.17	49.22	88.84
	II	.41	2.40	1.24	8.63	3.76	.33	.44	.67	31.62	88.19	1.51	56.56
	III	.24	1.45	1.03	4.06	1.32	.41	.27	.59	52.34	88.91	.91	42.18
	I+II			29.02	96.03	93.59	.96	.97	.04	195.76	89.71	75.34	89.2
	I+II+III			20.22	64.02	62.04	.98	.98	.02	592.40	89.90	129.61	89.56
4	W	6.41	76.96										
	I	.32	3.00	73.08	269.01	256.51	.95	.95	.05	85.42	89.33	66.14	89.13
	II	.16	1.94	1.94	12.50	5.70	.50	.46	.50	41.51	88.62	2.94	71.22
	III	.31	3.70	-1.76	6.00	-.44	-.91	-.06	1.91	20.12	87.15	-.12	-6.70
	I+II			37.51	134.51	131.11	.97	.97	.03	209.51	89.80	135.22	89.58
	I+II+III			24.42	89.67	87.26	.95	.97	.05	252.93	89.77	70.81	89.19
5	W	3.10	76.36										
	I	.24	5.70	70.66	345.37	327.17	.93	.95	.07	70.57	89.19	57.43	89.00
	II	.95	22.79	-17.09	10.20	-11.39	-3.00	-.63	4.00	2.78	70.24	-.50	-26.55
	III	.20	4.73	10.06	29.59	17.62	.79	.60	.21	19.55	87.07	3.73	74.98
	I+II			26.79	172.60	157.89	.70	.91	.30	26.99	87.88	13.86	85.87
	I+II+III			23.00	115.12	111.13	.94	.97	.06	212.96	89.73	70.53	89.19
6	W	3.20	157.56										
	I	.49	23.76	133.80	502.93	460.97	.85	.92	.15	22.55	87.46	19.41	87.05
	II	.25	12.12	11.64	41.96	.25	.49	.01	.51	6.19	80.83	.02	1.17
	III	.13	6.06	6.06	41.71	23.68	.50	.57	.50	16.25	86.48	3.91	75.65
	I+II			72.72	251.46	230.61	.92	.92	.08	62.74	89.09	38.05	88.49
	I+II+III			50.50	167.64	161.63	.96	.96	.04	191.11	99.70	80.02	89.28
7	W	2.12	203.62										
	I	.59	56.72	146.89	706.55	607.87	.72	.86	.28	12.04	85.25	10.72	84.67
	II	.15	14.54	42.18	98.68	42.43	.74	.43	.26	8.06	82.93	2.92	71.08
	III	.15	14.54	.00	56.25	23.68	.00	.42	1.00	6.77	81.60	1.63	58.44
	I+II			94.54	353.27	325.15	.93	.92	.07	65.28	89.12	44.71	88.72
	I+II+III			63.02	235.52	224.66	.93	.95	.07	92.63	89.38	46.34	88.76

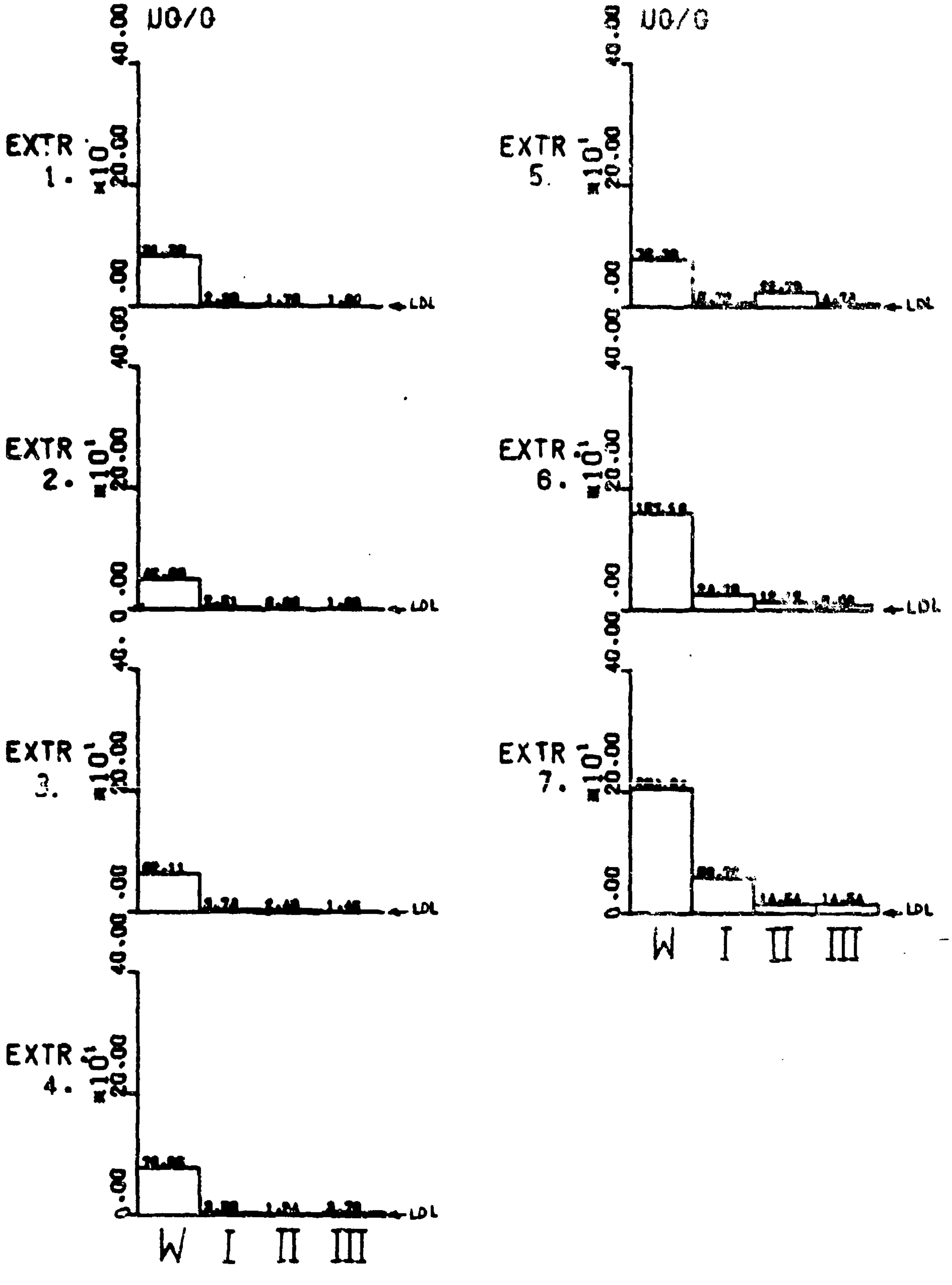


FIGURE 115. WEIGHT OF ZINC FROM ZINC SECONDARY-REFINING CINDERS ON NICHOLSON SOIL.

SECONDARY ZINC SMELTER SLUDGE

A scrubber installed on the stack of the zinc secondary smelter produced a sludge that was disposed of among the cinders. This sludge was quite soluble in water, yielding a slightly acidic extract which, by the second extraction, began to flush some ions off the soils and increase the conductivity. (Table 62 and Figures 116 and 121.)

TABLE 62. LEACHABILITY OF SECONDARY ZINC SMELTER SLUDGE

Element	Initial Conc. (µg/ml)	When Concentration Levels Off: Conc. (µg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days	Total Weight Extracted (µg/g waste)	Percentage Extracted
Cd	116.	0.08	7	190	620	410.	75.
Pb	9.5	7.5	7	190	620	1,540.	2.2
Ni	0.66	0.6	5	47	150	5.	1.4
Zn	605.	21.	7	190	620	11,600.	3.0

Measurement	Initial	Final	Estim.Tot.Extr. (µ equiv/g)
Conduct. (µ mho)	9,524.	148.	686.
pH	6.4	6.0	--

Cadmium

Cadmium was present in the first extract at a very high concentration (116 µg/ml), but this decreased to a low level (0.34 µg/ml) by the fifth extraction. (Tables 62 to 65 and Figure 122.) Of the cadmium present in the sludge, 75 percent (410 µg/g) was dissolved by the seven extractions. Figures 124 to 126 and the tabulated data show that all three soils began to yield cadmium either previously retained on the soil or originally present in the soil. Figure 123 shows that the cumulative fraction of cadmium retained by each soil is very dependent upon soil-to-waste ratio. Chalmers was the best of the three (Davidson was the poorest), but it also was steadily deteriorating in its ability to retain cadmium under the conditions produced by this extract.

Lead

The output of lead from this waste was at a moderate level averaging 7.8 µg/ml. With the six extractions totaling 190 milliliters of water per gram of waste, 1,540 micrograms of lead had been dissolved, which is 2.2 percent of the total present in the sludge. (Figure 127 and Tables 62, 66 to 68.) Figures 128 to 131 show that the retention of lead from this leachate was very high for all three soils even at a 1:1 soil-to-waste ratio. The overall retention for the seven extractions was at least 96 percent for all three soils at a 3:1 soil-to-waste ratio. The concentration of lead in the seventh

soil extract was 0.12 μg/ml for Chalmers and 0.24 μg/ml for Davidson and Nicholson soils.

Nickel

The concentration of nickel in the leachate was very low (0.66 μg/ml) and dropped steadily to near the lower detection limit by the fifth extract. (Tables 62, 69 to 73 and Figure 132.) A total of 5 micrograms of nickel was extracted per gram of waste, which is 1.4 percent of that present. The performance of the soils is displayed in Figures 133 to 136. Davidson retained the least nickel from the solution: 27 percent of the total challenge by the fourth extraction at the 3:1 soil-to-waste ratio; Chalmers and Nicholson retained 68 to 60 percent, respectively, under the same conditions.

Zinc

Zinc initially was present at a moderate concentration (605 μg/ml) which dropped steadily to 21 μg/ml by the seventh extraction. A total of 11,600 μg/ g was dissolved, which is 3.0 percent of the amount in the waste. (See Figures 137 to 141 and Tables 62, 72 to 74.) Davidson soil is also the least effective in removing this element from the leachate (50 percent) compared with Chalmers and Nicholson which removed 77 and 82 percent, respectively, from the cumulative challenge in seven extractions at a 3:1 soil-to-waste ratio. Figure 138 shows the important effect of the ratio of soil to waste in the retention of zinc from this leachate.

Summary

The sludge from the zinc secondary-refining plant produced a leachate with a very high initial cadmium concentration which then dropped to a low level. The soils passed only low levels of this metal, but began to give up cadmium previously retained, indicating the possibility of poor performance upon further exposure to this waste. Lead was retained very well by all three soils and only low concentrations penetrated them, but the waste appeared to be a long-term source of lead: the concentration of lead was moderately high in the waste extract throughout the period of leaching, and although only 2.2 percent of the lead was extracted during these tests, the waste is about 6.8 percent lead. Nickel was present only in very low concentrations and after passage through soil dropped below the detection limit. The zinc salts were sufficiently soluble at first to give a solution of moderate zinc concentration, but it dropped to a low concentration by the seventh extraction. Although only three percent of the zinc dissolved in this time, potentially leaving a long-term source (this waste was 38 percent zinc), the concentration should be very low unless influenced by external factors. The soils further reduced the zinc concentration, with Nicholson and Chalmers soils retaining about 80 percent, and Davidson soil 50 percent of the cumulative challenge.

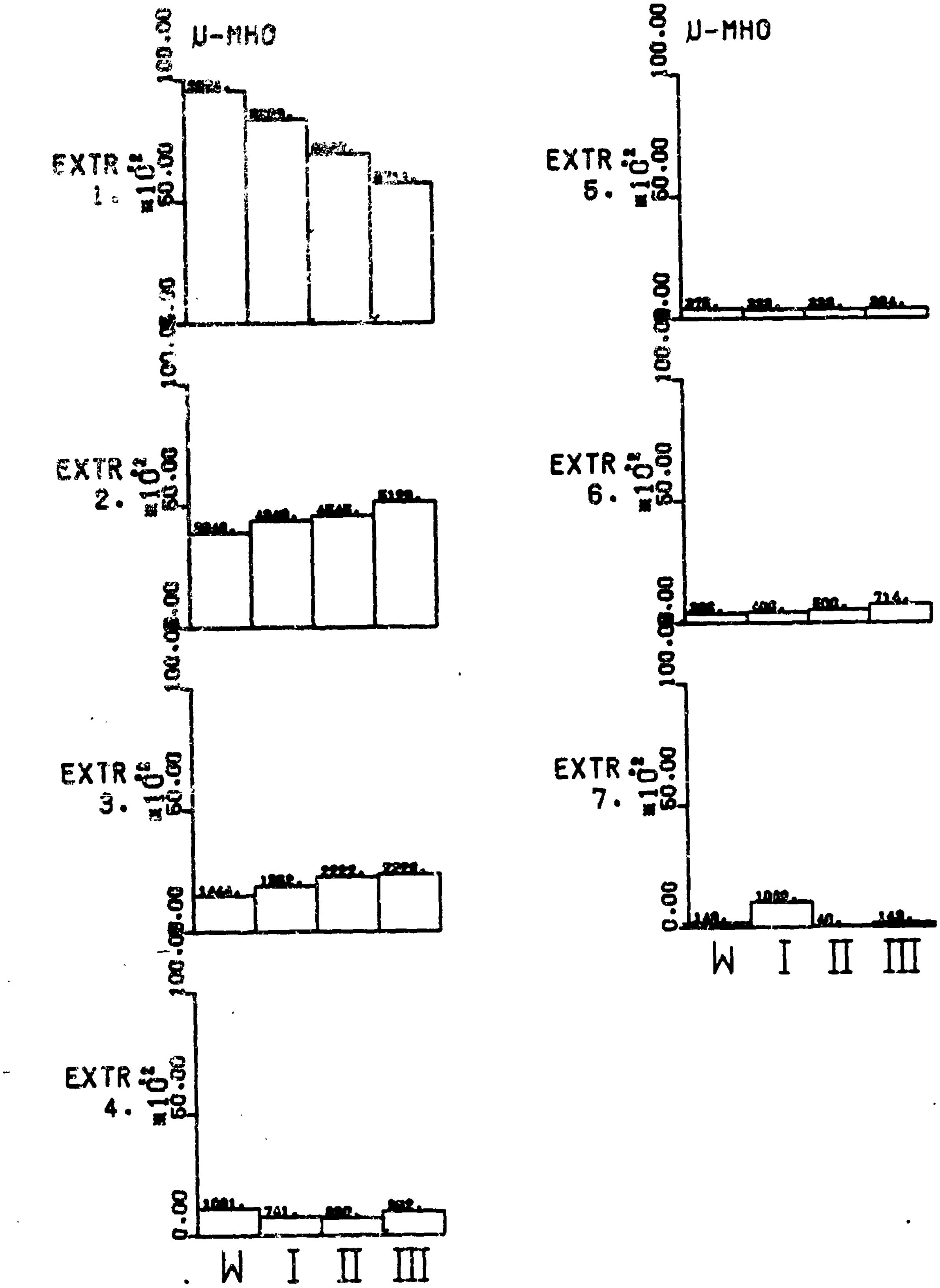


FIGURE 116. CONDUCTANCE OF EXTRACT FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

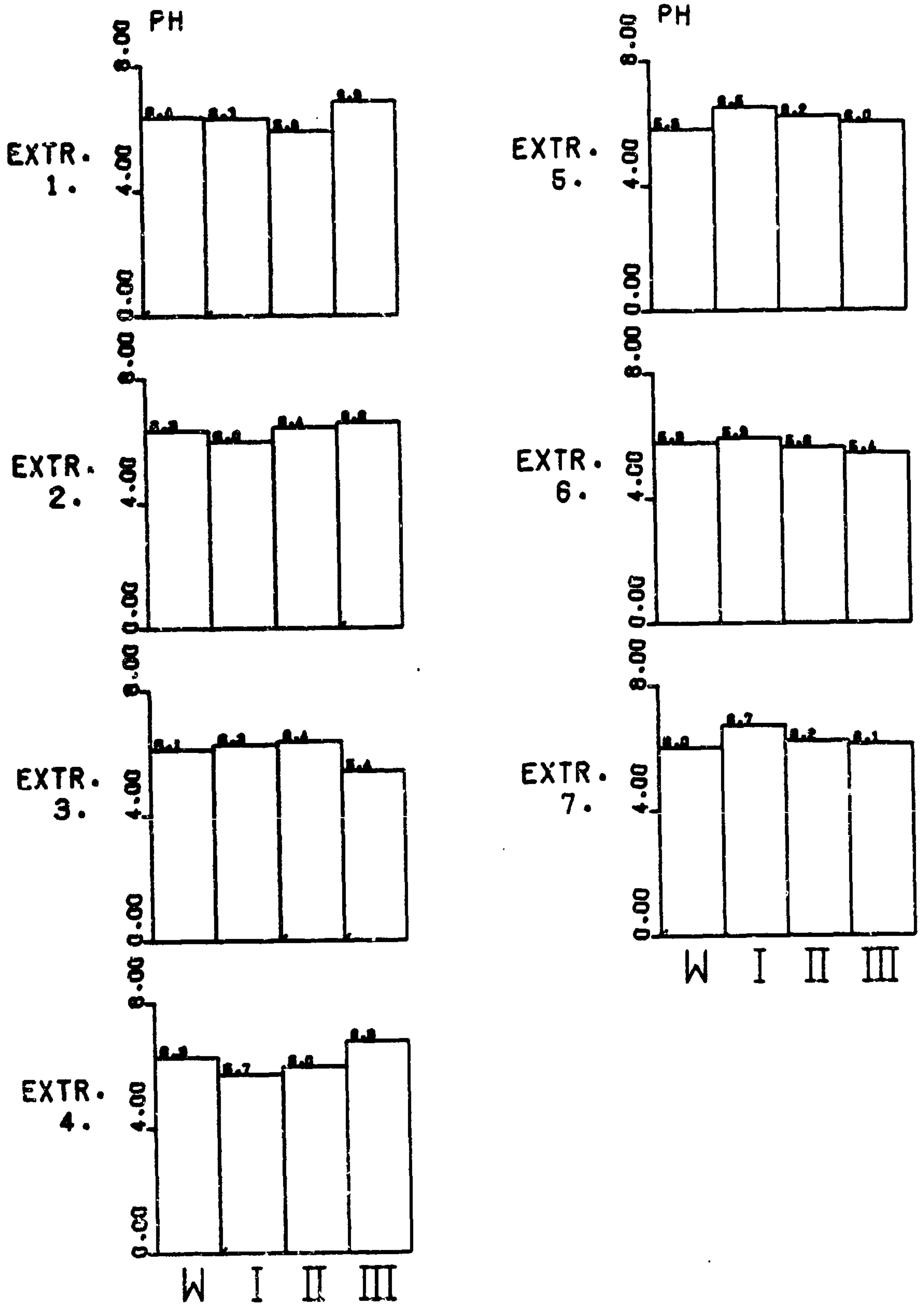


FIGURE 117. pH OF EXTRACT FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

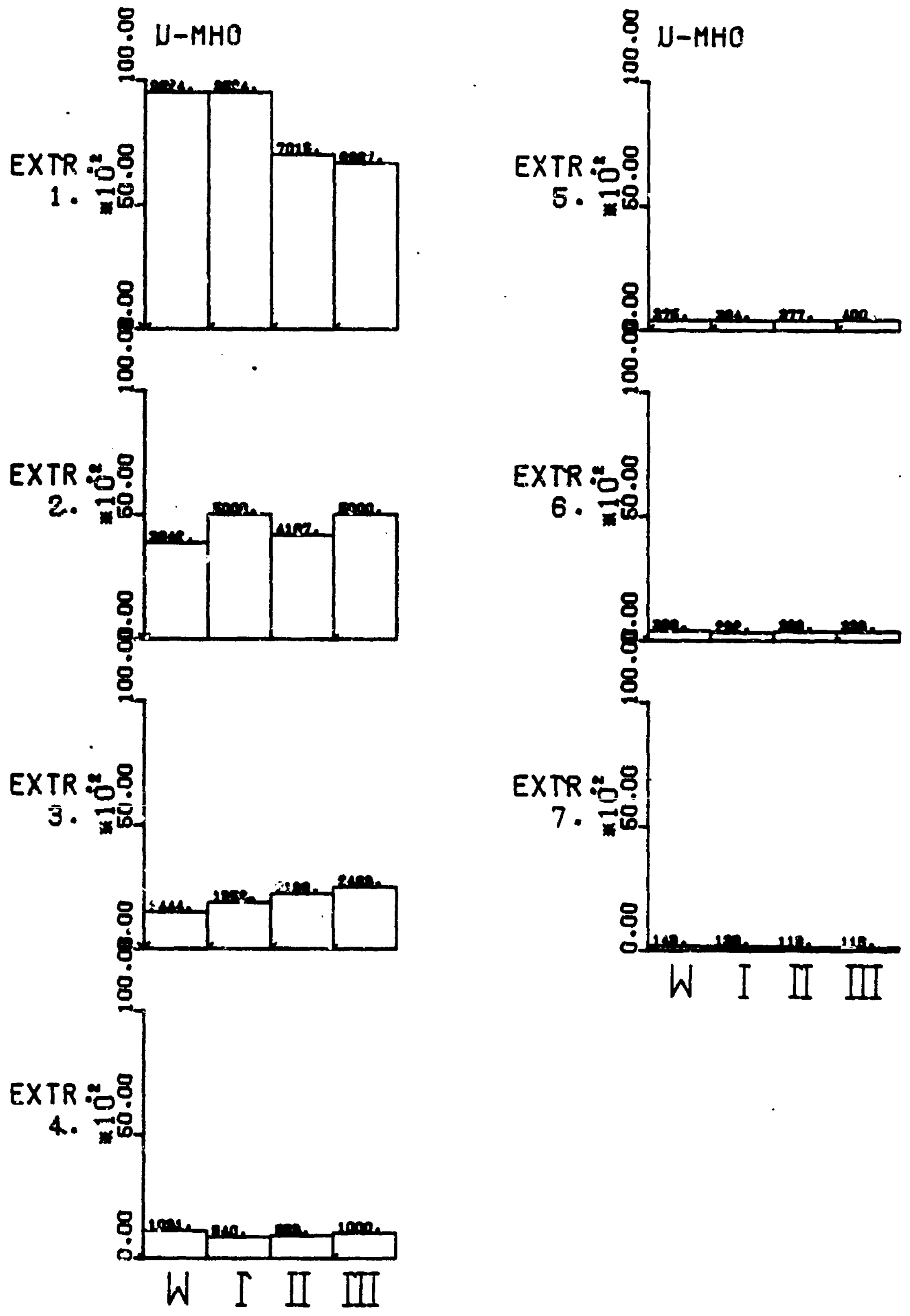


FIGURE 118. CONDUCTANCE OF EXTRACT FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

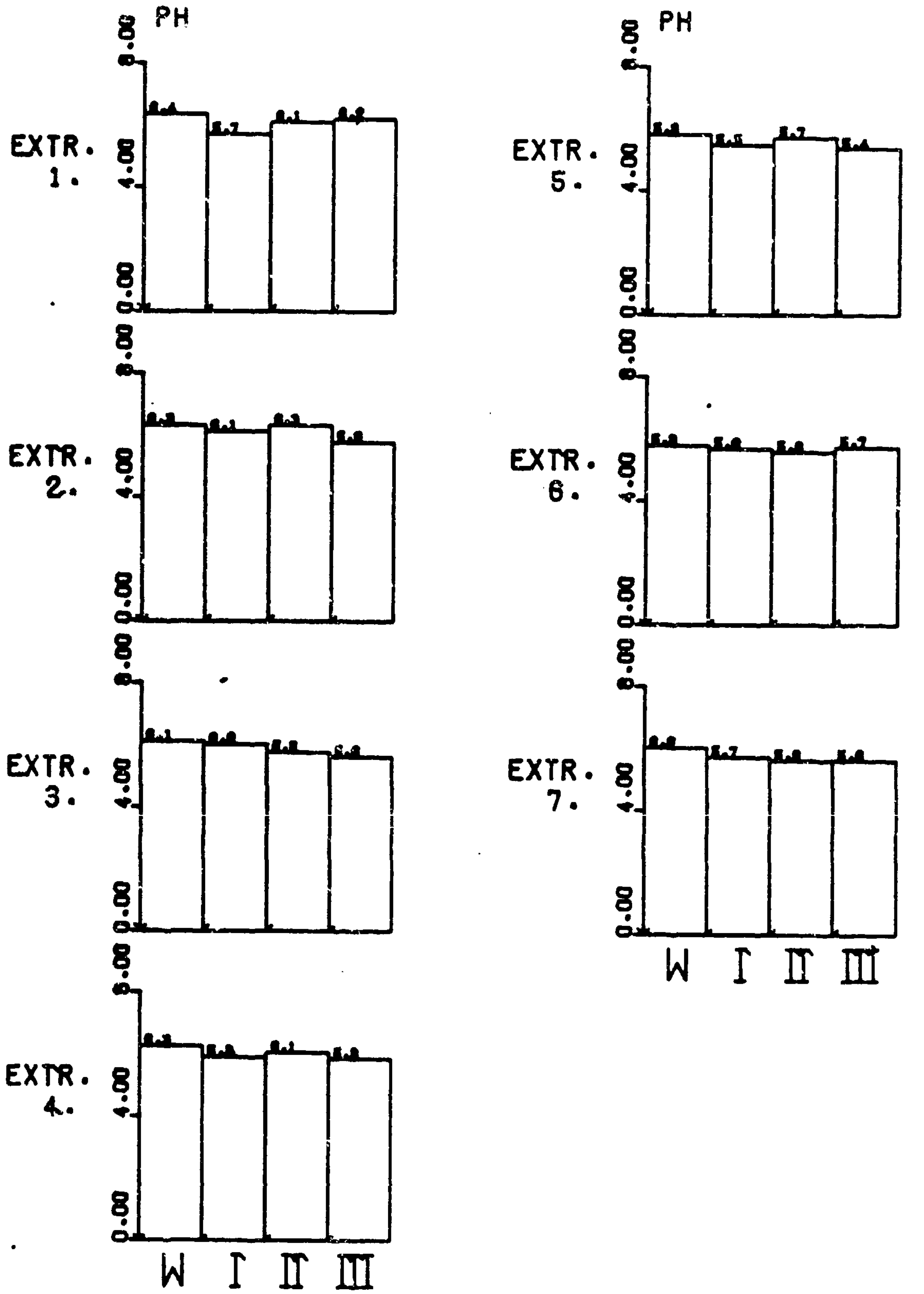


FIGURE 119. pH OF EXTRACT FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

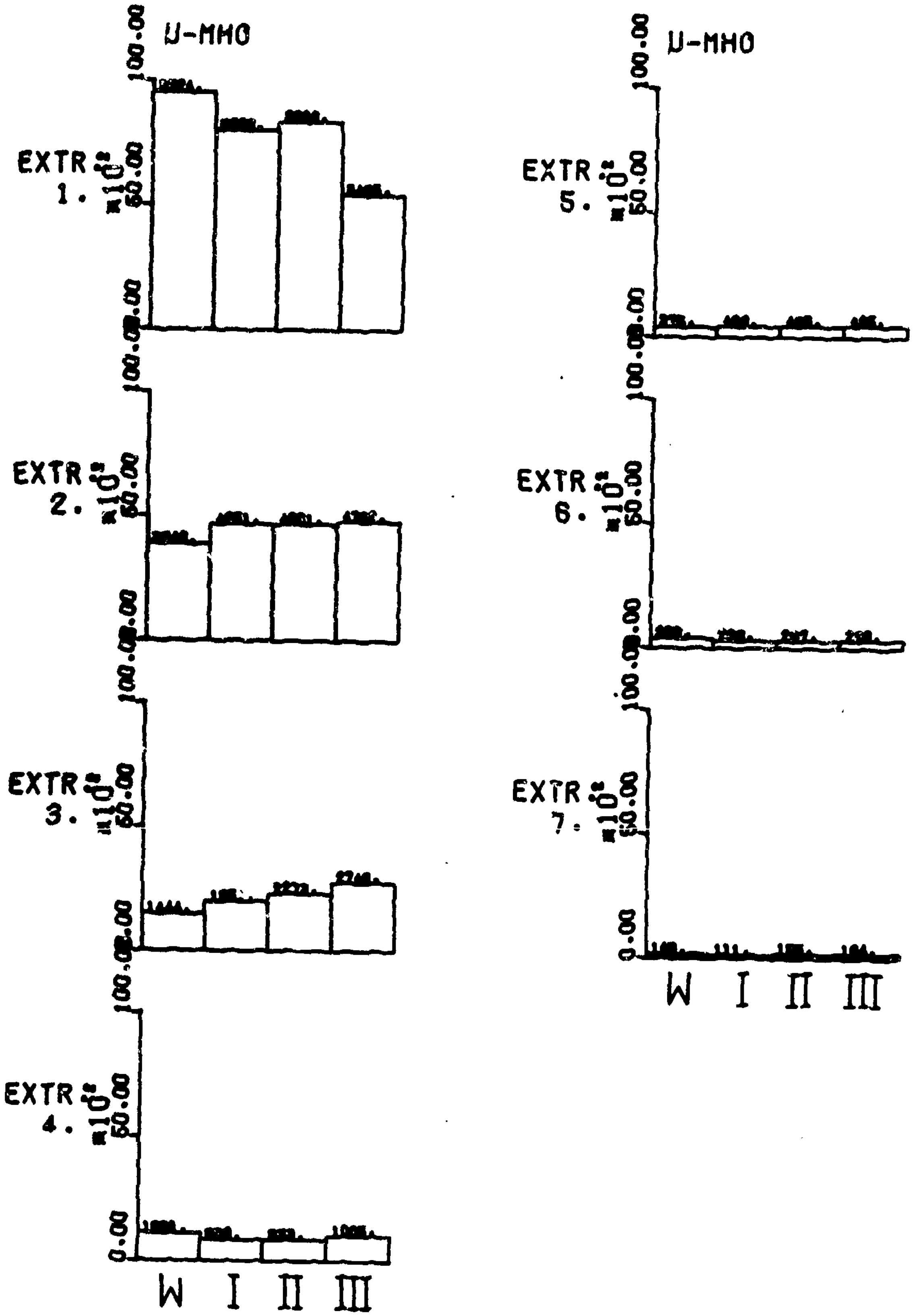


FIGURE 120. CONDUCTANCE OF EXTRACT FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

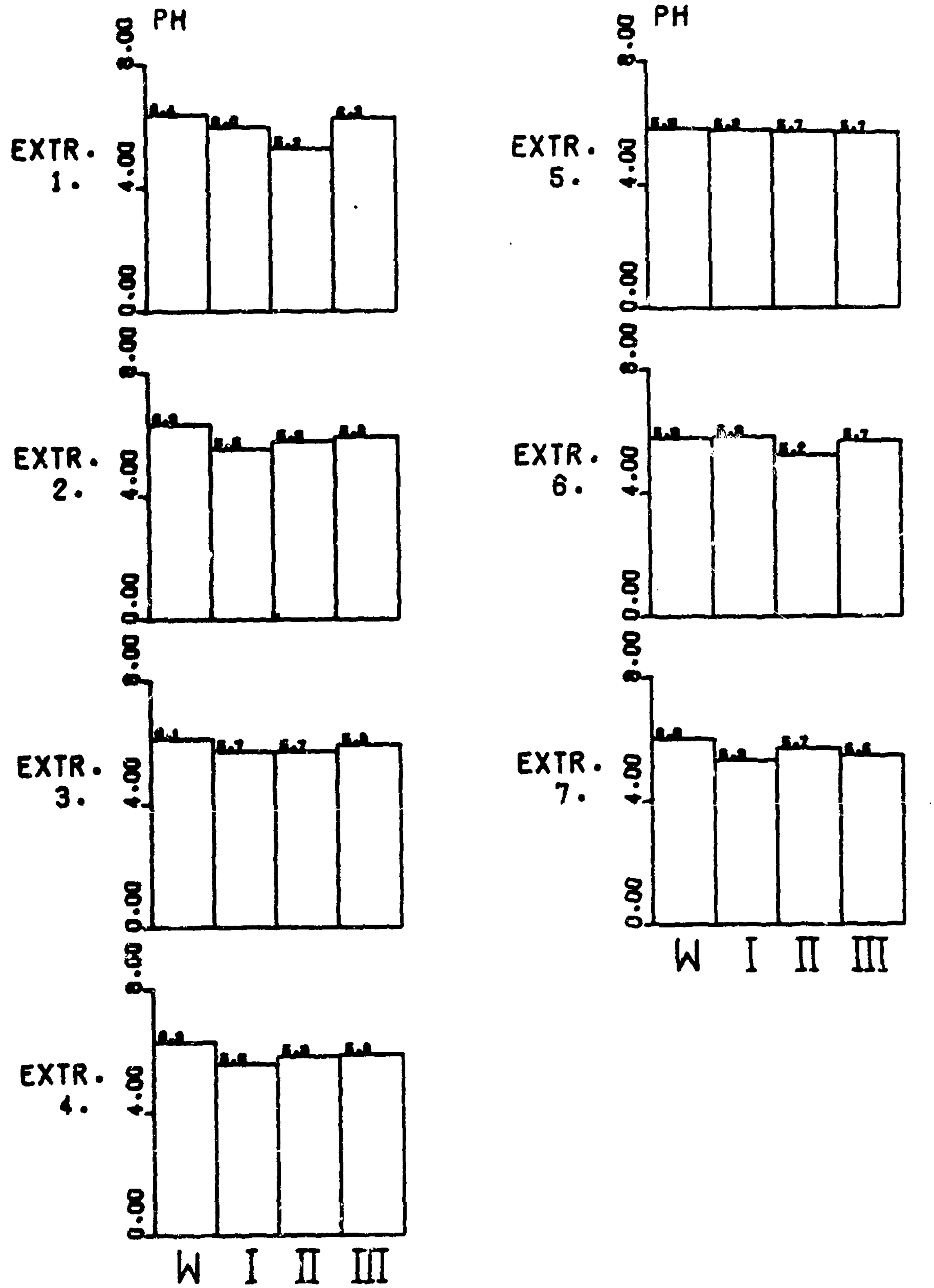


FIGURE 121. pH OF EXTRACT FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

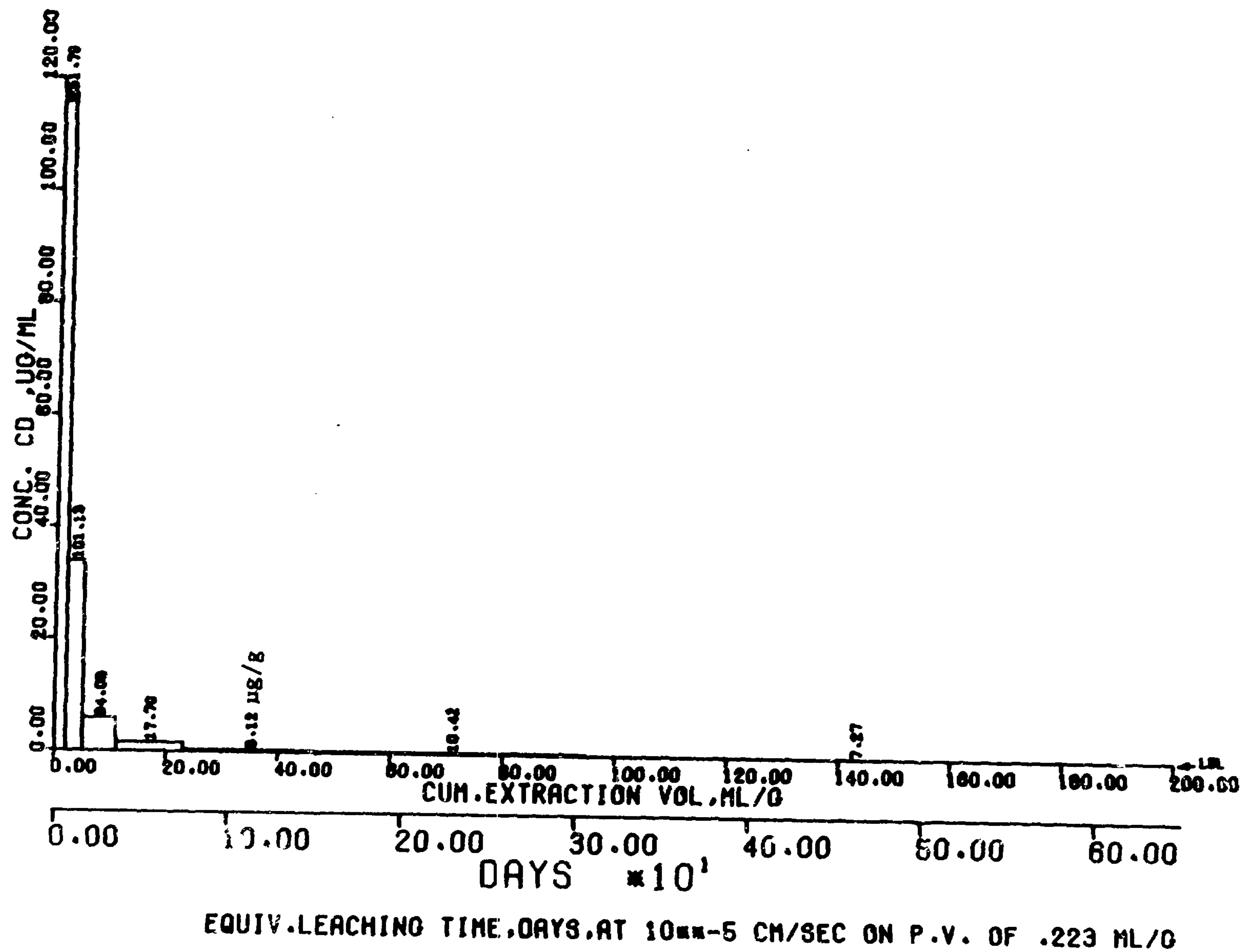


FIGURE 122. EXTRACTION OF CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE.

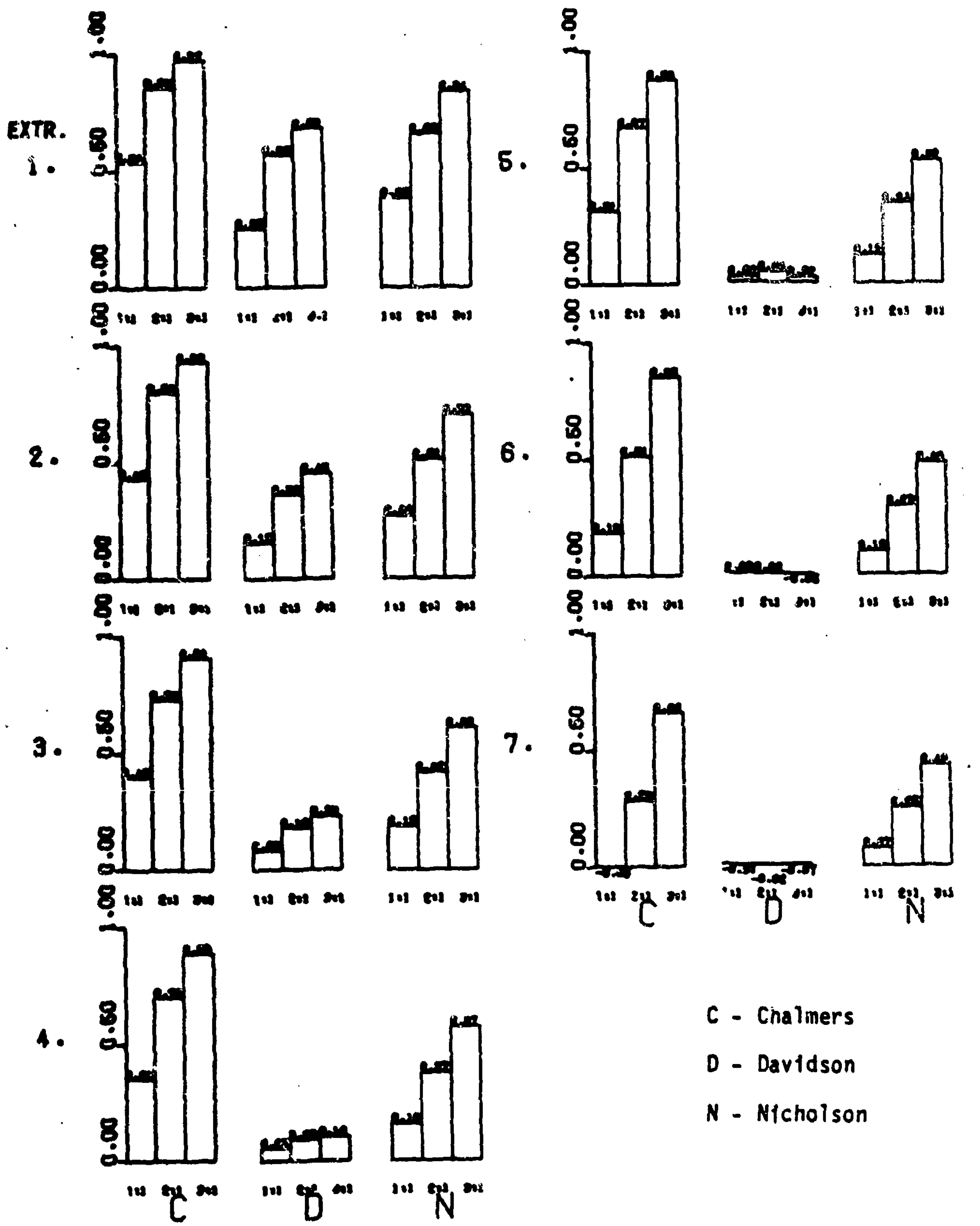


FIGURE 123. COMPARING FRACTION CADMIUM RETAINED BY SOILS FROM ZINC SECONDARY-REFINING SLUDGE LEACHATE.

TABLE 63. CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

EXT. NR.	LAYER	ANT. PENETR. UG/ML	ANT. PENETR. UG/G	ANT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	115.90	231.79										
	I	53.68	107.36	124.43	231.79	124.43	.54	.54	.46	1.16	49.33	1.16	49.21
	II	16.67	33.33	74.03	107.36	74.03	.69	.69	.31	2.24	65.91	2.22	65.76
	III	3.13	6.26	27.07	33.33	27.07	.81	.81	.19	4.40	77.20	4.32	76.97
	I+II			99.23	115.90	99.23	.86	.86	.14	6.01	80.56	5.95	80.47
	I+II+III			75.10	77.26	75.10	.97	.97	.03	36.73	88.44	36.02	88.41
2	W	33.71	101.13										
	I	27.72	83.17	17.95	332.92	142.38	.18	.43	.82	1.72	59.84	1.71	59.71
	II	11.51	34.54	40.63	190.54	122.66	.58	.64	.42	3.57	74.33	3.55	74.27
	III	5.86	17.57	16.97	67.07	44.04	.49	.65	.51	2.53	68.47	2.51	68.24
	I+II			33.29	166.46	132.52	.66	.80	.34	7.73	82.63	7.67	82.57
	I+II+III			27.05	110.97	103.03	.83	.93	.17	17.84	86.79	17.59	86.75
3	W	5.67	34.03										
	I	5.20	31.21	2.82	366.95	145.20	.08	.40	.92	4.67	77.91	4.65	77.87
	II	5.25	31.51	-.30	221.75	122.36	-.01	.55	1.01	3.90	75.61	3.88	75.56
	III	1.77	10.60	20.91	99.30	64.94	.66	.65	.34	6.17	80.80	6.12	80.73
	I+II			1.26	183.47	133.70	.07	.73	.93	8.55	83.33	8.49	83.28
	I+II+III			7.01	122.32	110.84	.69	.91	.31	31.70	88.20	31.35	88.17
4	W	1.47	17.70										
	I	2.37	28.40	-10.79	304.64	134.42	-.61	.35	1.61	4.74	78.08	4.72	78.04
	II	1.31	15.76	12.73	250.23	135.09	.45	.54	.55	8.61	83.37	8.57	83.35
	III	.71	8.40	7.27	115.14	72.22	.46	.63	.54	8.57	83.35	8.51	83.30
	I+II			.97	192.32	134.75	.11	.70	.89	17.23	86.68	17.10	86.65
	I+II+III			3.07	128.21	113.91	.52	.89	.48	40.81	88.60	40.28	88.58
5	W	.34	8.12										
	I	.80	19.15	-11.03	392.76	123.39	-1.36	.31	2.36	6.47	81.21	6.44	81.18
	II	.60	14.30	4.85	269.38	139.94	.25	.52	.75	9.82	84.19	9.78	84.16
	III	.25	6.06	8.24	129.44	80.46	.58	.62	.42	13.36	85.72	13.28	85.69
	I+II			-3.09	196.38	131.66	-.76	.67	1.76	18.55	86.91	18.41	86.89
	I+II+III			.69	130.92	114.59	.25	.88	.75	57.47	89.00	56.73	88.99
6	W	.22	10.42										
	I	1.26	60.60	-50.18	403.19	73.21	-4.81	.18	5.81	1.22	50.57	1.21	50.38
	II	1.41	67.87	-7.27	329.98	132.66	-.12	.40	1.12	1.96	62.99	1.95	62.91
	III	.25	12.12	55.75	197.31	136.21	.82	.69	.18	11.28	84.93	11.24	84.92
	I+II			-28.72	201.59	102.94	-5.51	.51	6.51	3.06	71.92	3.03	[illegible]
	I+II+III			-.57	134.40	114.03	-.16	.85	1.16	28.60	88.00	28.22	87.97
7	W	.08	7.27										
	I	1.11	106.66	-99.38	410.46	-26.17	-13.67	-.06	14.67	-.24	-13.53	-.25	-13.79
	II	1.01	96.96	9.70	436.63	142.36	.09	.33	.91	1.47	55.83	1.47	55.74
	III	.83	79.51	17.45	294.27	153.66	.18	.52	.82	1.94	62.72	1.93	62.64
	I+II			-44.84	205.23	58.09	-12.33	.28	13.33	1.22	50.63	1.20	50.15
	I+II+III			-24.08	136.82	89.95	-9.93	.66	10.93	3.45	73.84	3.39	73.58

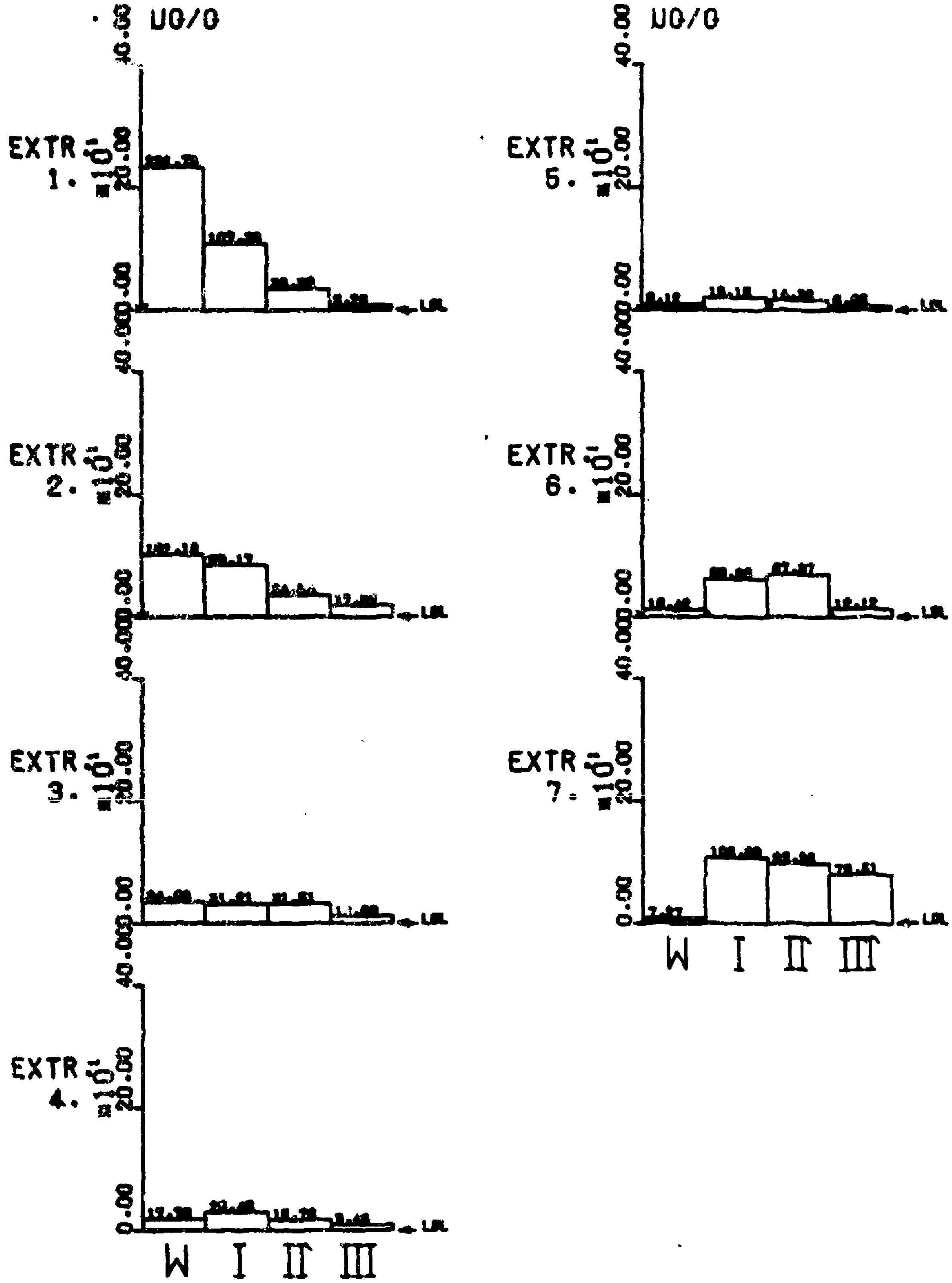


FIGURE 124. WEIGHT OF CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

TABLE 64. CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	115.90	231.79										
	I	86.61	173.21	58.58	231.79	58.58	.25	.25	.75	.35	19.11	.34	18.69
	II	50.50	101.00	72.21	173.21	72.21	.42	.42	.58	.73	36.11	.71	35.56
	III	37.17	74.34	26.66	101.00	26.66	.26	.26	.74	.38	20.72	.36	19.73
	I+II			65.40	115.90	65.40	.56	.56	.44	1.35	53.52	1.29	52.32
	I+II+III			52.49	77.26	52.49	.68	.68	.32	2.29	66.44	2.12	64.73
2	W	33.71	101.13										
	I	36.56	109.69	-8.56	332.92	50.02	-.08	.15	1.08	.47	25.14	.46	24.51
	II	37.57	112.72	-3.03	282.90	69.19	-.03	.24	1.03	.63	32.07	.61	31.54
	III	36.46	109.38	3.33	213.72	30.00	.03	.14	.97	.29	16.04	.27	15.34
	I+II			-5.79	166.46	59.60	-.11	.36	1.11	1.11	47.96	1.06	46.60
	I+II+III			-2.75	110.97	49.73	-.08	.45	1.08	1.48	56.01	1.36	53.75
3	W	5.67	34.03										
	I	9.14	54.84	-20.82	366.95	29.20	-.61	.08	1.61	.56	29.20	.53	28.04
	II	14.80	88.78	-33.94	337.74	35.25	-.62	.10	1.62	.41	22.46	.40	21.66
	III	16.61	99.60	-10.91	302.49	19.09	-.12	.06	1.12	.21	11.64	.19	10.81
	I+II			-27.38	183.47	32.23	-1.61	.18	2.61	.79	38.36	.73	35.98
	I+II+III			-21.09	122.32	27.85	-1.93	.23	2.93	.97	44.10	.84	39.96
4	W	1.47	17.70										
	I	2.22	26.66	-8.97	384.64	20.24	-.51	.05	1.51	.81	39.12	.76	37.19
	II	3.99	47.87	-21.21	364.41	14.04	-.80	.04	1.80	.32	17.93	.29	16.34
	III	5.20	62.42	-14.54	350.37	4.54	-.30	.01	1.30	.10	5.49	.07	4.16
	I+II			-15.09	192.32	17.14	-1.71	.09	2.71	.84	39.93	.72	35.60
	I+II+III			-14.91	128.21	12.94	-2.53	.10	3.53	.83	39.73	.62	31.88
5	W	.34	8.12										
	I	.82	19.63	-11.51	392.76	8.72	-1.42	.02	2.42	.52	27.39	.44	23.95
	II	1.08	25.82	-6.18	384.04	7.86	-.31	.02	1.31	.36	19.83	.30	16.93
	III	1.62	38.78	-12.97	376.18	-8.42	-.50	-.02	1.50	-.18	-10.19	-.22	-12.25
	I+II			-8.85	196.38	8.29	-2.18	.04	3.18	.87	40.92	.64	32.71
	I+II+III			-10.22	130.92	2.72	-3.78	.02	4.78	.55	28.67	.21	11.88
6	W	.22	10.42										
	I	.38	18.18	-7.76	403.19	.96	-.74	.00	1.74	.13	7.57	.05	3.04
	II	.55	26.18	-8.06	402.22	-.14	-.44	-.00	1.44	.05	2.86	-.01	-.31
	III	.78	37.33	-11.15	402.36	-19.57	-.43	-.05	1.43	-.49	-25.90	-.52	-27.67
	I+II			-7.08	201.59	.41	-1.51	.00	2.51	.25	14.20	.03	1.80
	I+II+III			-8.97	134.40	-6.25	-2.58	-.05	3.58	-.15	-8.68	-.50	-26.67
7	W	.08	7.27										
	I	.11	10.67	-3.39	410.46	-2.43	-.47	-.01	1.47	-.09	-5.25	-.23	-12.83
	II	.17	16.00	-5.33	412.89	-5.47	-.50	-.01	1.50	-.25	-14.12	-.34	-18.89
	III	.17	16.00	-.00	418.36	-19.57	-.00	-.05	1.00	-1.13	-48.56	-1.22	-50.74
	I+II			-4.36	205.23	-3.95	-1.20	-.02	2.20	-.13	-7.49	-.49	-26.29
	I+II+III			-2.91	136.82	-9.16	-1.20	-.07	2.20	-.90	-42.04	-1.72	-59.79

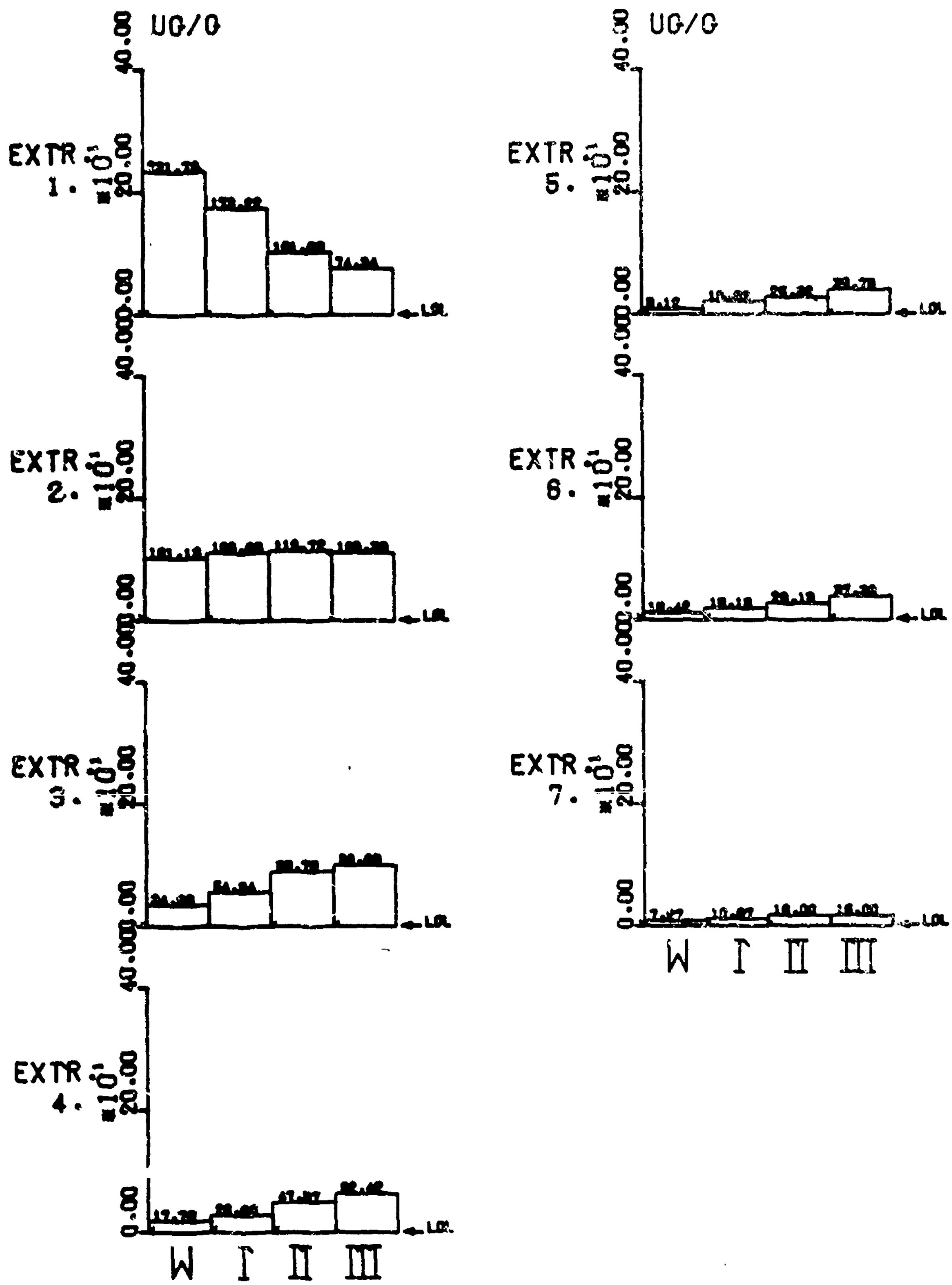


FIGURE 125. WEIGHT OF CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

TABLE 65. CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	115.90	231.79										
	I	71.76	143.52	88.27	231.79	88.27	.38	.38	.62	.62	31.74	.62	31.59
	II	39.95	79.89	63.63	143.52	63.63	.44	.44	.56	.88	38.75	.86	38.54
	III	18.63	37.27	42.62	79.89	42.62	.53	.53	.47	1.16	49.16	1.14	48.83
	I+II			75.95	115.90	75.95	.66	.66	.34	1.93	62.57	1.90	62.26
	I+II+III			64.84	77.26	64.84	.84	.84	.16	5.34	79.39	5.22	79.15
2	W	33.71	101.13										
	I	33.83	101.51	-.38	332.92	87.90	-.00	.26	1.00	.87	41.05	.87	40.89
	II	27.93	83.78	17.73	245.03	81.36	.17	.33	.83	.98	44.33	.97	44.16
	III	20.91	62.72	21.06	163.67	63.60	.25	.39	.75	1.02	45.66	1.02	45.43
	I+II			0.67	166.46	84.63	.17	.51	.83	2.04	63.93	2.02	63.66
	I+II+III			12.00	110.97	77.64	.30	.70	.62	3.79	75.20	3.71	74.93
3	W	5.67	34.03										
	I	9.19	55.15	-21.12	366.95	66.78	-.62	.18	1.62	1.22	50.66	1.21	50.45
	II	8.40	50.90	4.24	308.17	85.60	.08	.29	.92	1.69	59.41	1.60	59.26
	III	7.52	45.15	5.76	214.57	69.44	.11	.32	.89	1.55	57.16	1.54	56.97
	I+II			-8.44	183.47	76.19	-.50	.42	1.50	3.03	71.75	2.99	71.53
	I+II+III			-3.71	122.32	73.94	-.33	.60	1.33	5.01	78.72	4.91	78.50
4	W	1.47	17.70										
	I	2.02	24.24	-6.54	384.64	60.23	-.37	.16	1.37	2.51	68.24	2.48	68.08
	II	2.17	26.06	-1.82	324.41	83.78	-.08	.26	1.08	3.23	72.82	3.22	72.72
	III	1.67	20.00	6.06	240.63	75.50	.23	.31	.77	3.80	75.26	3.78	75.16
	I+II			-4.18	192.32	72.01	-.47	.37	1.47	5.60	79.88	5.53	79.74
	I+II+III			-.77	128.21	73.17	-.13	.57	1.13	11.28	84.90	10.98	84.79
5	W	.34	8.12										
	I	.91	21.94	-13.82	392.76	46.41	-1.70	.12	2.70	2.14	64.94	2.12	64.70
	II	.76	18.30	3.64	346.35	87.42	.17	.25	.83	4.80	78.24	4.78	78.18
	III	.94	22.54	-4.24	258.93	71.26	-.23	.28	1.23	3.18	72.56	3.16	72.44
	I+II			-5.09	196.30	66.92	-1.25	.34	2.25	7.42	82.33	7.31	82.21
	I+II+III			-4.81	130.92	60.36	-1.70	.52	2.70	9.30	83.86	9.10	83.73
6	W	.22	10.42										
	I	.37	17.94	-7.51	403.19	38.90	-.72	.10	1.72	2.20	65.52	2.17	65.24
	II	.56	26.66	-8.73	364.29	70.67	-.49	.22	1.49	2.97	71.39	2.95	71.28
	III	.48	23.27	3.39	285.60	74.65	.13	.26	.87	3.23	72.79	3.21	72.69
	I+II			-8.12	201.59	50.79	-1.56	.29	2.56	4.49	77.43	4.41	77.22
	I+II+III			-4.26	134.40	64.00	-1.23	.48	2.23	8.45	83.25	8.26	83.10
7	W	.08	7.27										
	I	.18	16.97	-9.70	410.46	29.20	-1.33	.07	2.33	1.75	60.26	1.72	59.84
	II	.25	23.76	-6.79	381.25	71.90	-.40	.19	1.40	3.05	71.84	3.03	71.72
	III	.25	23.76	.00	309.35	74.65	.00	.24	1.00	3.16	72.46	3.14	72.35
	I+II			-8.24	265.23	50.55	-2.27	.25	3.27	4.34	77.03	4.26	76.78
	I+II+III			-5.49	136.82	50.59	-2.27	.43	3.27	7.59	82.49	7.40	82.30

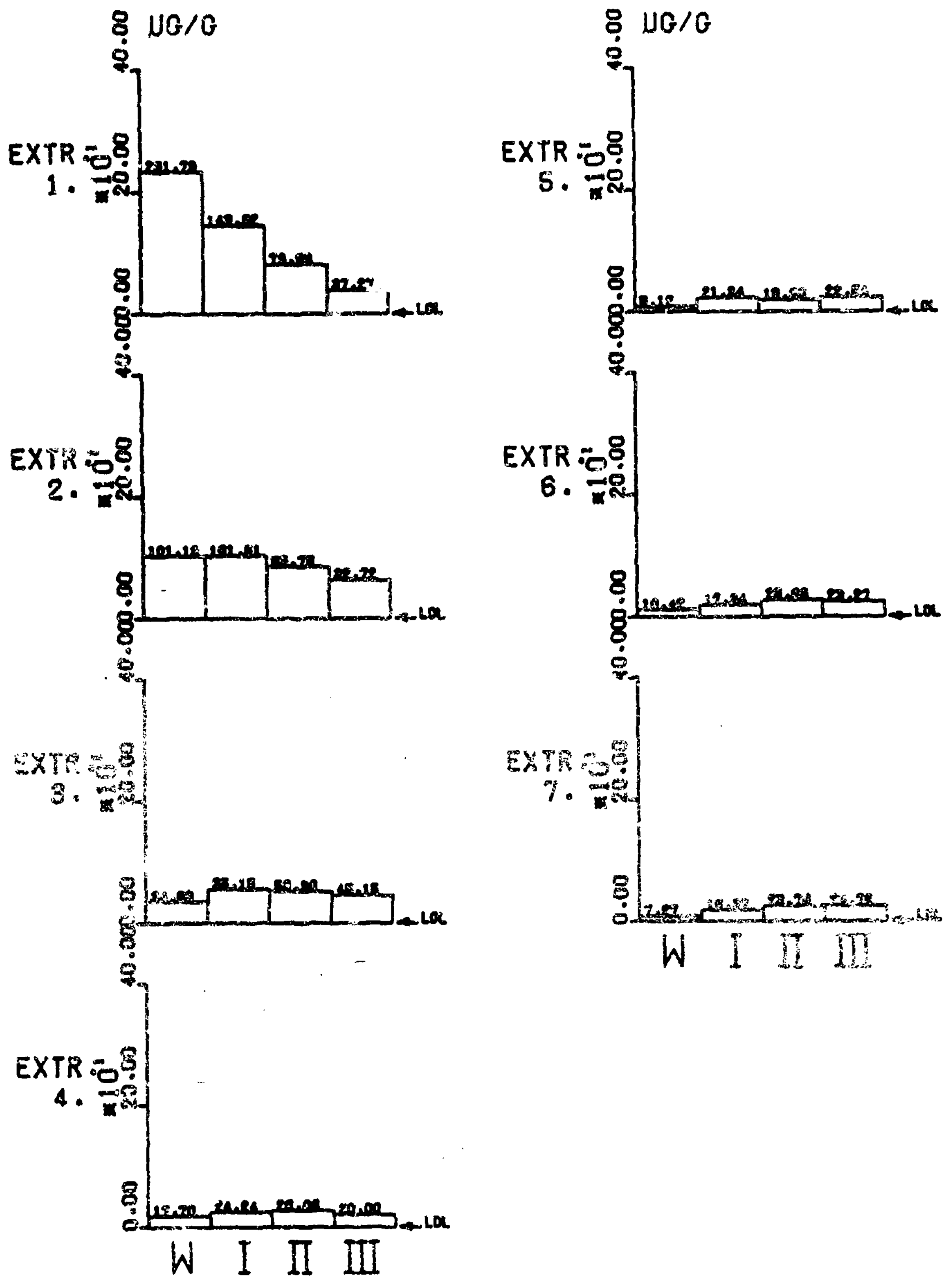


FIGURE 126. WEIGHT OF CADMIUM FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

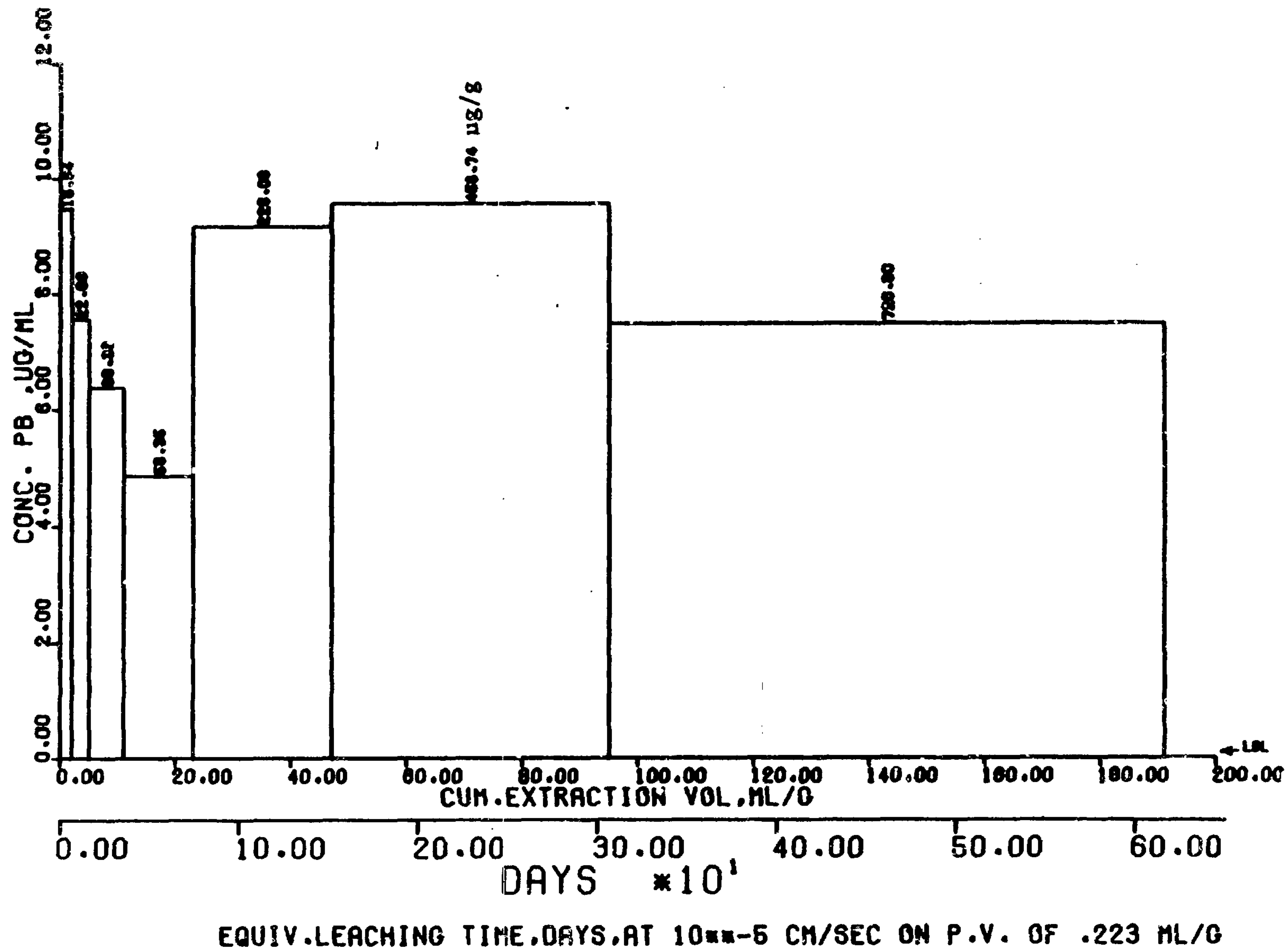
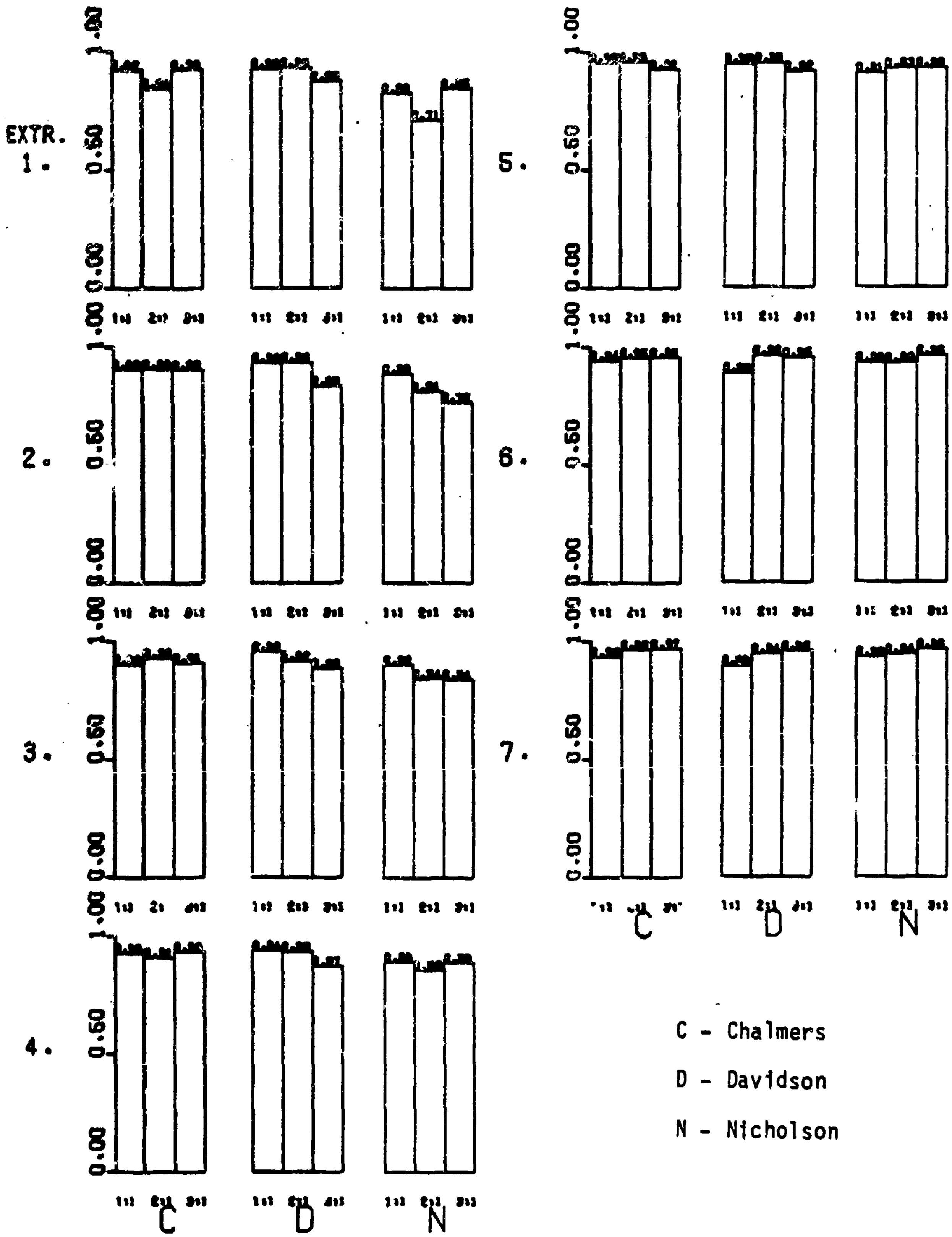


FIGURE 127. EXTRACTION OF LEAD FROM ZINC SECONDARY-REFINING SLUDGE.



C - Chalmers

D - Davidson

N - Nicholson

FIGURE 128. COMPARING FRACTION LEAD RETAINED BY SOILS FROM ZINC SECONDARY-REFINING SLUDGE LEACHATE.

TABLE 66. LEAD FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	9.47	18.94										
	I	.73	1.46	17.48	18.94	17.48	.92	.92	.08	79.38	89.28	11.96	85.22
	II	1.47	2.95	-1.49	1.46	-1.49	-1.02	-1.02	2.02	32.90	88.26	-.50	-26.77
	III	.70	1.41	1.54	2.95	1.54	.52	.52	.48	71.14	89.19	1.10	47.64
	I+II			7.99	9.47	7.99	.84	.84	.16	139.04	89.59	5.42	79.55
	I+II+III			5.84	6.31	5.84	.93	.93	.07	642.84	89.91	12.47	85.41
2	W	7.56	22.69										
	I	.85	2.56	20.13	41.62	37.61	.89	.90	.11	53.26	88.92	14.72	86.11
	II	.35	1.04	1.52	4.02	.03	.59	.01	.41	94.95	89.40	.03	1.65
	III	.89	2.66	-1.62	3.99	-.08	-1.56	-.02	2.56	37.04	88.45	-.03	-1.67
	I+II			10.82	20.81	18.82	.95	.90	.05	415.95	89.86	36.27	88.42
	I+II+III			6.68	13.87	12.52	.88	.90	.12	347.72	89.84	14.13	85.95
3	W	6.39	38.33										
	I	.64	3.87	34.46	79.95	72.07	.90	.90	.10	44.10	08.70	18.63	86.93
	II	.29	1.75	2.12	7.88	2.15	.55	.27	.45	57.51	89.00	1.23	50.82
	III	.53	3.20	-1.45	5.74	-1.52	-.83	-.27	1.83	30.34	88.11	-.48	-25.49
	I+II			18.29	39.98	37.11	.95	.93	.05	267.55	89.79	42.41	88.65
	I+II+III			11.71	26.65	24.23	.92	.91	.08	300.06	89.81	22.74	87.48
4	W	4.86	58.35										
	I	.20	2.36	55.98	138.30	128.05	.96	.93	.04	95.81	89.40	54.15	88.94
	II	.58	7.00	-4.64	10.25	-2.49	-1.96	-.24	2.96	13.71	85.83	-.36	-19.59
	III	.16	1.93	5.08	12.74	3.56	.73	.28	.27	53.00	88.92	1.85	61.56
	I+II			25.67	69.15	62.78	.88	.91	.12	74.17	89.23	17.92	86.81
	I+II+III			18.81	46.10	43.04	.97	.93	.03	527.46	89.89	67.05	89.15
5	W	9.17	220.03										
	I	.26	6.24	213.79	358.32	341.83	.97	.95	.03	70.57	89.19	54.78	88.95
	II	.10	2.40	3.84	16.49	1.35	.62	.08	.38	41.50	88.62	.56	29.30
	III	.74	17.77	-15.37	15.14	-11.81	-6.40	-.78	7.40	4.88	78.42	-.66	-33.62
	I+II			108.81	179.16	171.59	.99	.96	.01	307.16	89.81	142.99	89.60
	I+II+III			67.42	119.44	110.46	.92	.92	.08	68.54	89.16	18.65	86.93
6	W	9.56	458.74										
	I	.67	32.23	426.51	817.06	768.35	.93	.94	.07	26.90	87.87	23.84	67.60
	II	.50	2[illegible].06	8.17	48.71	9.52	.25	.20	.75	4.49	77.45	.40	21.59
	III	.23	11.12	12.94	39.20	1.12	.54	.03	.46	8.96	83.65	.10	5.76
	I+II			217.34	408.53	388.93	.95	.95	.05	48.72	88.82	32.34	88.23
	I+II+III			149.21	272.35	259.66	.98	.95	.02	149.78	89.62	70.06	89.18
7	W	7.51	720.80										
	I	.57	54.84	665.95	1537.86	1434.30	.92	.93	.08	27.95	87.95	26.15	87.81
	II	.17	15.87	38.98	103.56	48.50	.71	.47	.29	9.27	83.84	3.06	71.88
	III	.12	11.59	4.27	55.06	5.40	.27	.10	.73	8.96	83.63	.47	24.97
	I+II			352.47	768.93	741.40	.98	.96	.02	118.30	89.52	93.46	09.39
	I+II+III			236.40	512.62	496.06	.98	.97	.02	204.88	89.72	128.40	89.55

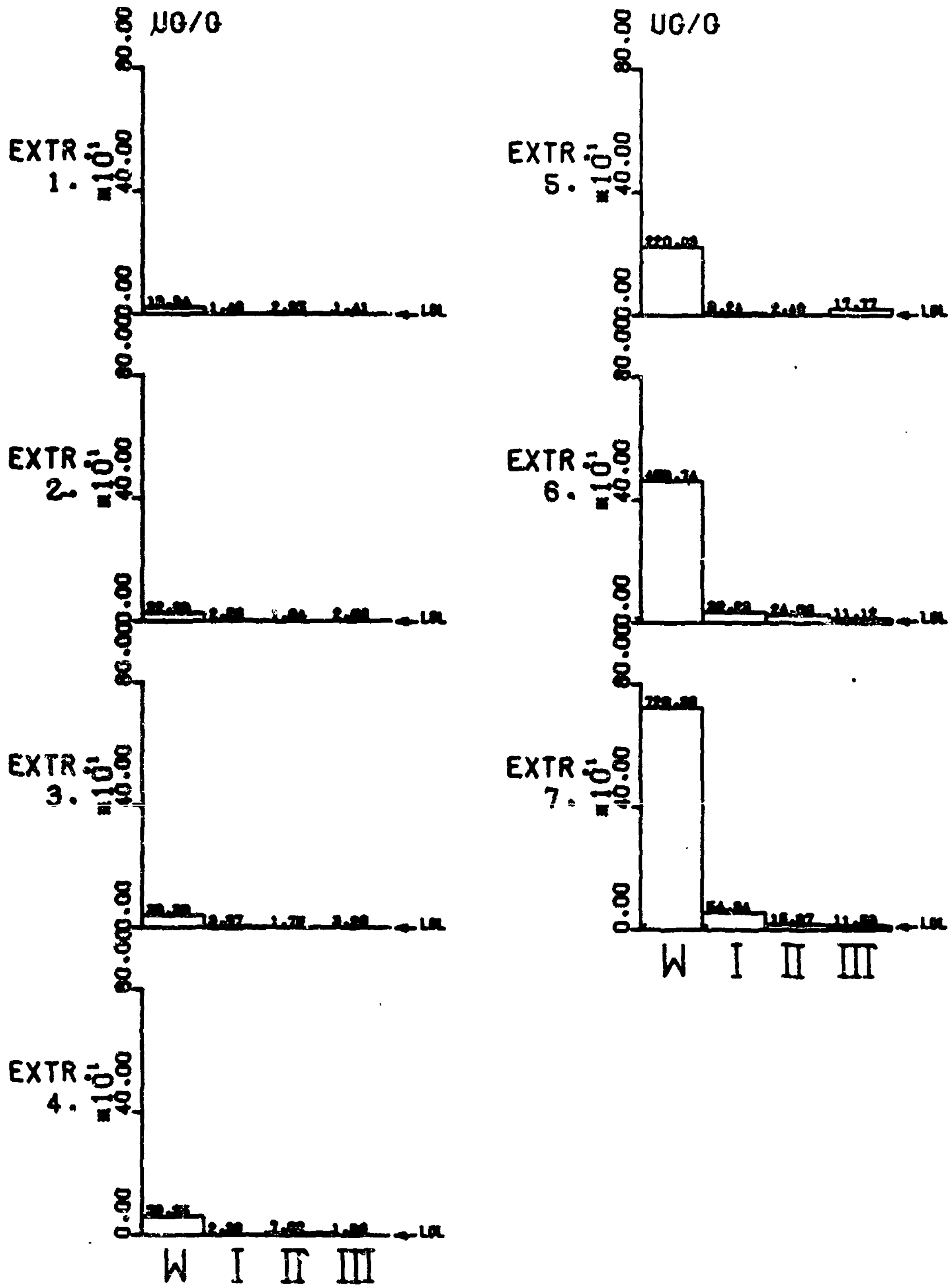


FIGURE 129. WEIGHT OF LEAD FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

TABLE 67. LEAD FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	9.47	18.94										
	I	.66	1.33	17.61	18.94	17.61	.93	.93	.07	129.29	89.56	13.27	85.69
	II	.62	1.25	.08	1.33	.08	.06	.06	.94	123.72	89.54	.07	3.77
	III	1.17	2.34	-1.09	1.25	-1.09	-.88	-.88	1.88	65.45	89.12	-.47	-25.03
	I+II			8.85	9.47	8.85	.93	.93	.07	508.83	89.89	14.21	85.97
	I+II+III			5.53	6.31	5.53	.88	.88	.12	600.34	89.90	7.11	81.99
2	W	7.56	22.69										
	I	.52	1.55	21.13	41.62	38.74	.93	.93	.07	124.03	89.54	24.93	87.70
	II	.51	1.54	.01	2.88	.09	.01	.03	.99	99.83	89.43	.06	3.43
	III	1.55	4.65	-3.11	2.79	-4.20	-2.01	-1.51	3.01	32.19	88.22	-.90	-42.07
	I+II			10.57	20.81	19.42	.93	.93	.07	424.24	89.86	25.16	87.72
	I+II+III			6.01	13.87	11.54	.79	.83	.21	305.28	89.81	7.44	82.35
3	W	6.39	38.33										
	I	.10	.60	37.73	79.95	76.47	.98	.96	.02	384.11	89.85	127.45	89.55
	II	.65	3.93	-3.33	3.48	-3.24	-5.55	-.93	6.55	38.37	88.51	-.82	-39.40
	III	.37	2.22	1.71	6.72	-2.49	.43	-.37	.57	68.24	89.16	-1.12	-48.30
	I+II			17.20	39.90	36.62	.90	.92	.10	175.41	89.67	10.64	86.93
	I+II+III			12.04	26.65	23.58	.94	.88	.06	656.11	89.91	31.86	88.20
4	W	4.86	58.35										
	I	.42	5.08	53.27	138.30	129.74	.91	.94	.09	55.89	88.98	25.56	87.76
	II	.20	2.36	2.71	8.56	-.52	.53	-.06	.47	64.93	89.12	-.22	-12.51
	III	.72	8.60	-6.23	9.08	-8.73	-2.64	-.96	3.64	16.90	86.61	-1.01	-45.42
	I+II			27.99	69.15	64.61	.96	.93	.04	315.25	89.82	54.66	88.95
	I+II+III			16.58	46.10	40.16	.85	.87	.15	175.21	89.67	14.01	85.92
5	W	9.17	220.03										
	I	.45	10.75	209.28	358.32	339.02	.95	.95	.05	45.87	88.75	31.54	88.18
	II	.35	8.36	2.39	19.31	1.86	.22	.10	.78	18.64	86.93	.22	12.54
	III	.52	12.38	-4.02	17.45	-12.74	-.48	-.73	1.48	11.41	84.99	-1.03	-45.93
	I+II			105.83	179.16	170.44	.96	.95	.04	114.41	89.50	40.76	88.59
	I+II+III			69.22	119.44	109.38	.94	.92	.06	138.46	89.59	26.51	87.84
6	W	9.56	458.74										
	I	1.58	75.70	383.04	817.06	722.05	.83	.88	.17	11.57	85.06	9.54	84.01
	II	.35	16.66	59.04	95.01	60.90	.78	.64	.22	12.90	85.57	3.65	74.70
	III	.23	10.91	5.76	34.11	-6.98	.35	-.20	.65	13.48	85.76	-.64	-32.63
	I+II			221.04	408.53	391.48	.96	.96	.04	83.95	89.32	46.98	88.78
	I+II+III			149.28	272.35	258.66	.98	.95	.02	198.25	89.71	71.15	89.19
7	W	7.51	720.00										
	I	.72	68.96	651.04	1537.86	1373.89	.90	.89	.10	22.16	87.42	19.92	87.13
	II	.53	50.92	18.03	163.97	78.93	.26	.48	.74	4.57	77.67	1.55	57.17
	III	.24	22.65	28.27	85.03	21.29	.56	.25	.44	7.74	82.64	.94	43.22
	I+II			334.94	768.93	726.41	.93	.94	.07	40.63	88.59	28.53	87.99
	I+II+III			232.71	512.62	491.37	.97	.96	.03	126.26	89.55	65.08	89.12

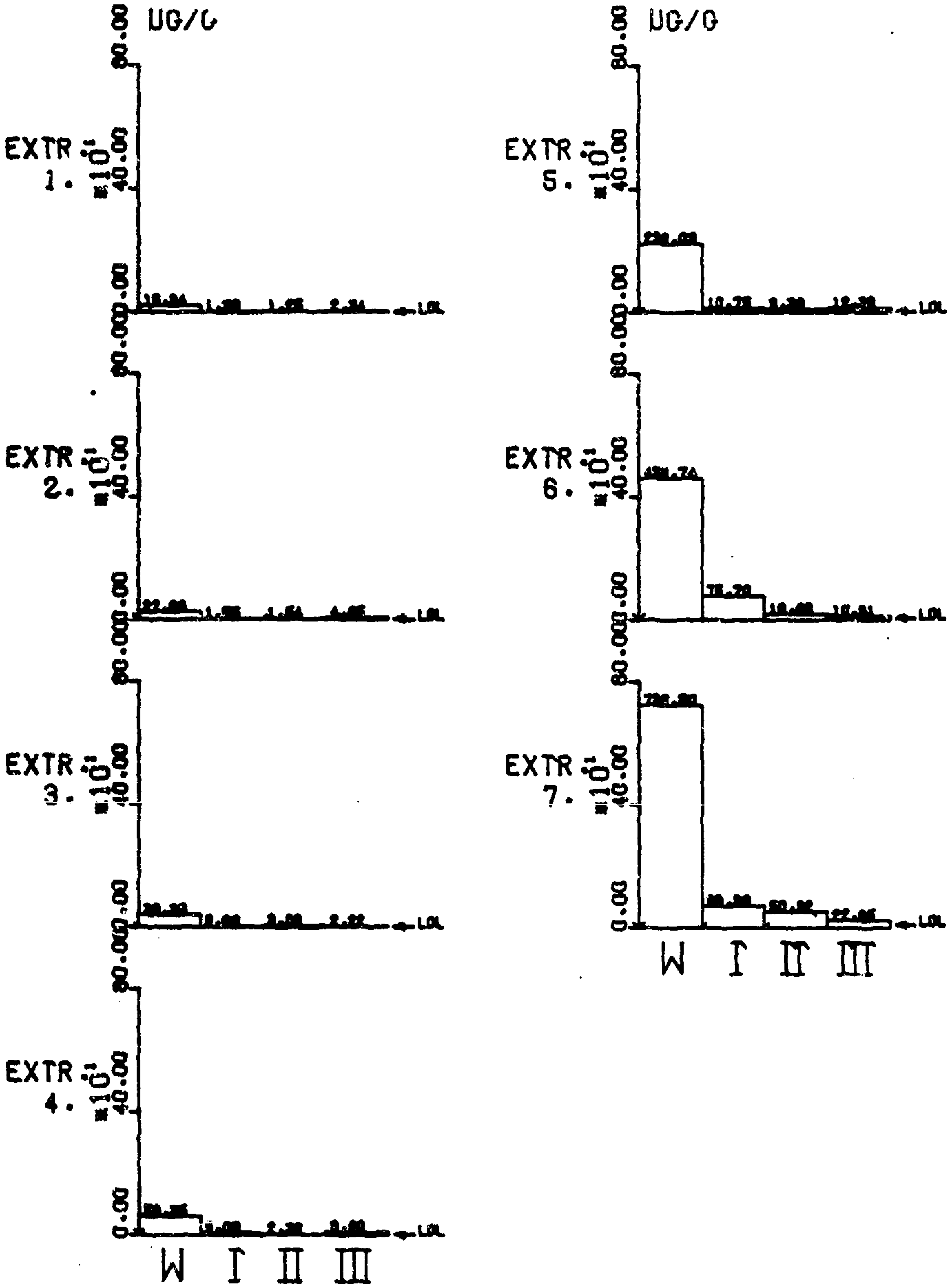


FIGURE 130. WEIGHT OF LEAD FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

TABLE 68. LEAD FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	9.47	18.94										
	I	1.65	3.30	15.64	18.94	15.64	.83	.83	.17	34.90	88.36	4.74	78.08
	II	2.73	5.47	-2.16	3.30	-2.16	-.66	-.66	1.66	17.83	86.79	-.40	-21.60
	III	1.45	2.09	2.57	5.47	2.57	.47	.47	.53	35.29	88.38	.89	41.60
	I+II			6.74	9.47	6.74	.71	.71	.29	75.36	89.24	2.47	67.92
	I+II+III			5.35	6.31	5.35	.85	.85	.15	315.18	89.82	5.54	79.77
2	W	7.56	22.69										
	I	.49	1.47	21.21	41.62	36.85	.94	.89	.06	92.65	89.30	25.02	87.71
	II	.81	2.42	-.95	4.77	-3.11	-.65	-.65	1.65	39.01	88.56	-1.29	-52.11
	III	2.31	6.92	-4.50	7.09	-1.93	-1.86	-.24	2.86	14.18	85.94	-.28	-15.58
	I+II			10.13	20.81	16.87	.89	.81	.11	178.30	89.68	13.92	85.89
	I+II+III			5.25	13.07	10.60	.69	.76	.31	134.04	89.57	4.59	77.72
3	W	6.39	30.33										
	I	.53	3.20	35.12	79.95	71.97	.92	.90	.08	53.59	88.93	22.48	87.45
	II	.79	4.77	-1.57	7.98	-4.68	-.49	-.59	1.49	19.91	87.13	-.98	-44.47
	III	.51	3.08	1.69	12.66	-.24	.35	-.02	.65	32.27	88.23	-.08	-4.51
	I+II			16.78	37.98	33.65	.88	.84	.12	97.70	89.41	14.12	85.95
	I+II+III			11.75	26.65	22.35	.92	.84	.08	312.92	89.82	21.78	87.37
4	W	4.06	58.35										
	I	.60	7.17	51.18	138.30	123.15	.88	.89	.12	31.07	88.16	17.18	86.67
	II	.61	7.30	-.13	15.15	-4.81	-.02	-.32	1.02	12.99	85.60	-.66	-33.38
	III	.22	2.66	4.63	19.96	4.39	.63	.22	.37	39.83	88.53	1.65	58.76
	I+II			25.52	69.15	59.17	.87	.86	.13	70.79	89.19	16.21	86.47
	I+II+III			18.56	46.10	40.91	.95	.89	.05	382.49	89.85	46.06	88.76
5	W	9.17	220.03										
	I	.78	18.60	201.43	358.32	324.58	.92	.91	.08	22.81	87.49	17.45	86.72
	II	.27	6.48	12.12	33.75	7.31	.65	.22	.35	16.58	86.53	1.13	48.44
	III	.43	10.23	-3.75	26.44	.64	-.58	.02	1.58	9.88	84.17	.06	3.60
	I+II			106.77	179.16	165.94	.97	.93	.03	112.70	89.49	51.22	88.88
	I+II+III			69.93	119.44	110.84	.95	.93	.05	120.14	89.52	32.51	88.24
6	W	9.56	458.74										
	I	.50	24.13	434.61	817.06	759.18	.95	.93	.05	35.59	88.39	31.46	88.18
	II	.67	32.14	-8.01	57.88	-.70	-.33	-.01	1.33	3.08	72.00	-.02	-1.25
	III	.15	7.44	24.71	58.58	25.35	.77	.43	.23	16.80	86.59	3.41	73.65
	I+II			213.30	408.53	379.24	.93	.93	.07	35.99	88.41	23.60	87.57
	I+II+III			150.43	272.35	261.28	.98	.96	.02	225.92	89.75	105.79	89.46
7	W	7.51	720.80										
	I	.54	51.75	669.05	1537.86	1428.23	.93	.93	.07	29.52	88.06	27.60	87.92
	II	.30	28.48	23.27	109.63	22.57	.45	.21	.55	4.29	76.88	.79	38.39
	III	.24	22.87	5.61	87.06	30.96	.20	.36	.80	5.71	80.06	1.35	53.54
	I+II			346.16	768.93	725.40	.96	.94	.04	64.93	89.12	50.94	88.88
	I+II+III			232.64	512.62	493.92	.97	.96	.03	103.96	89.45	64.78	89.12

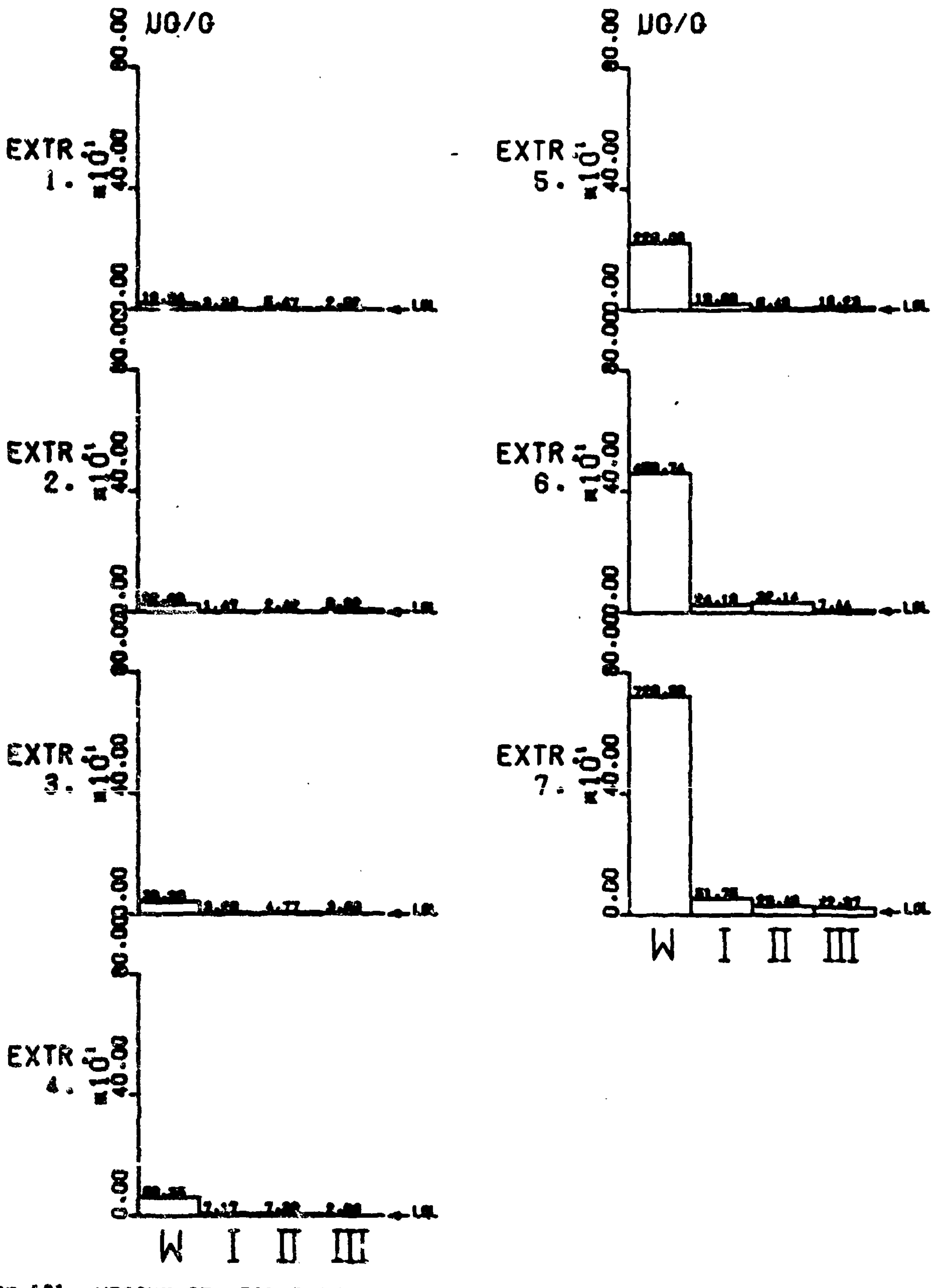


FIGURE 131. WEIGHT OF LEAD FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

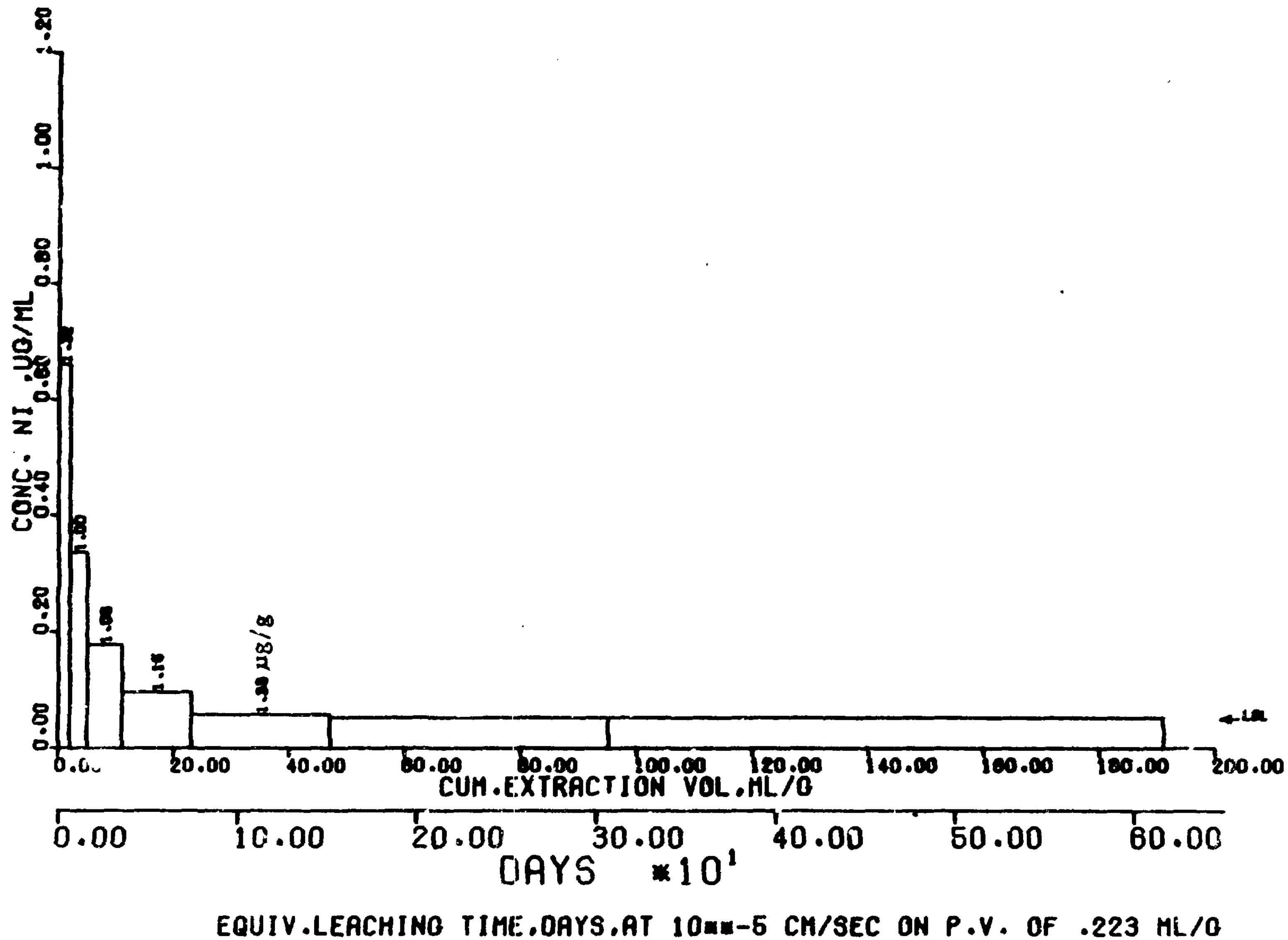


FIGURE 132. EXTRACTION OF NICKEL FROM ZINC SECONDARY-REFINING SLUDGE.

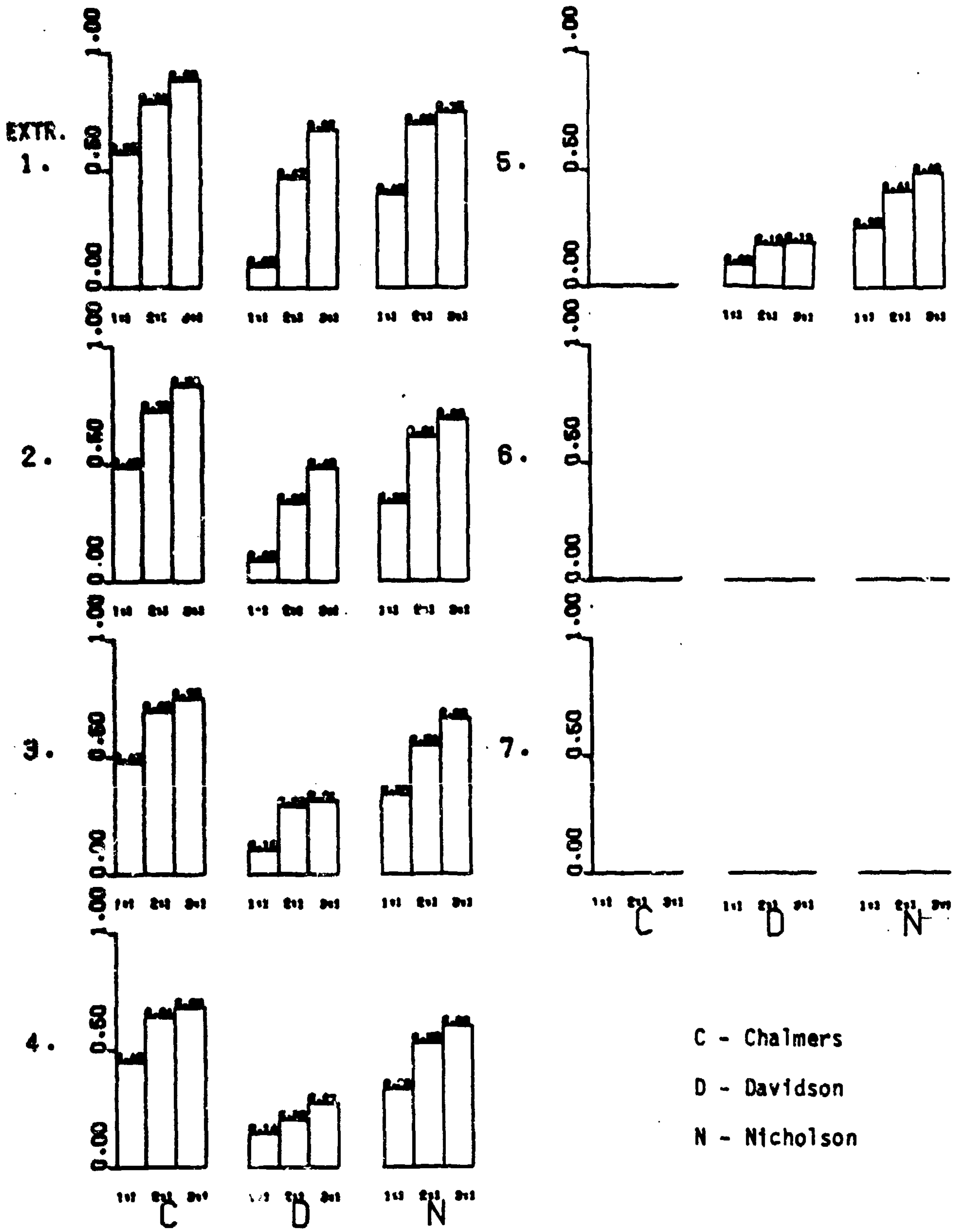


FIGURE 133. COMPARING FRACTION NICKEL RETAINED BY SOILS FROM ZINC SECONDARY-REFINING SLUDGE LEACHATE.

TABLE 69. NICKEL FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.66	1.32										
	I	.28	.57	.76	1.32	.76	.57	.57	.43	44.83	88.72	1.34	53.25
	II	.14	.28	.28	.57	.28	.50	.50	.50	87.99	89.35	1.00	45.00
	III	.08	.15	.13	.28	.13	.46	.46	.54	163.24	89.65	.87	49.91
	I+II			.52	.66	.52	.79	.79	.21	351.63	89.84	3.68	74.79
	I+II+III			.39	.44	.39	.89	.89	.11	1469.12	89.96	7.73	82.63
2	W	.33	1.00										
	I	.21	.64	.36	2.32	1.12	.36	.48	.64	40.42	88.58	1.76	60.42
	II	.12	.36	.27	1.21	.54	.43	.46	.57	69.18	89.17	1.53	56.79
	III	.08	.24	.12	.65	.25	.33	.39	.67	102.53	89.44	1.04	46.17
	I+II			.32	1.16	.84	.64	.72	.36	275.24	89.79	4.61	77.76
	I+II+III			.25	.77	.64	.76	.83	.24	921.32	89.94	7.96	82.84
3	W	.18	1.06										
	I	.10	.58	.48	3.38	1.61	.46	.47	.54	45.52	88.74	2.79	70.28
	II	.07	.39	.18	1.78	.74	.32	.41	.68	64.32	89.11	1.87	61.89
	III	.08	.46	-.06	1.04	.19	-.15	.18	1.15	54.55	88.95	.42	22.89
	I+II			.33	1.69	1.17	.63	.69	.37	255.76	89.78	5.95	80.46
	I+II+III			.28	1.13	.85	.57	.75	.43	492.71	89.88	5.58	79.84
4	W	.10	1.15										
	I	.06	.73	.42	4.53	2.03	.37	.45	.63	36.62	88.44	2.79	70.29
	II	<.05	<.61	.12	2.51	.86	.17	.34	.83	42.01	88.64	1.42	54.78
	III	<.05	<.61	.00	1.65	.19	.00	.12	1.00	40.91	88.60	.32	17.57
	I+II			.27	2.27	1.44	.47	.64	.53	167.14	89.66	4.77	78.15
	I+II+III			.18	1.51	1.03	.47	.68	.53	370.43	89.85	5.08	78.87
5	W	.06	1.33										
	I	<.05	<1.21										
	II	<.05	<1.21										
	III	<.05	<1.21										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

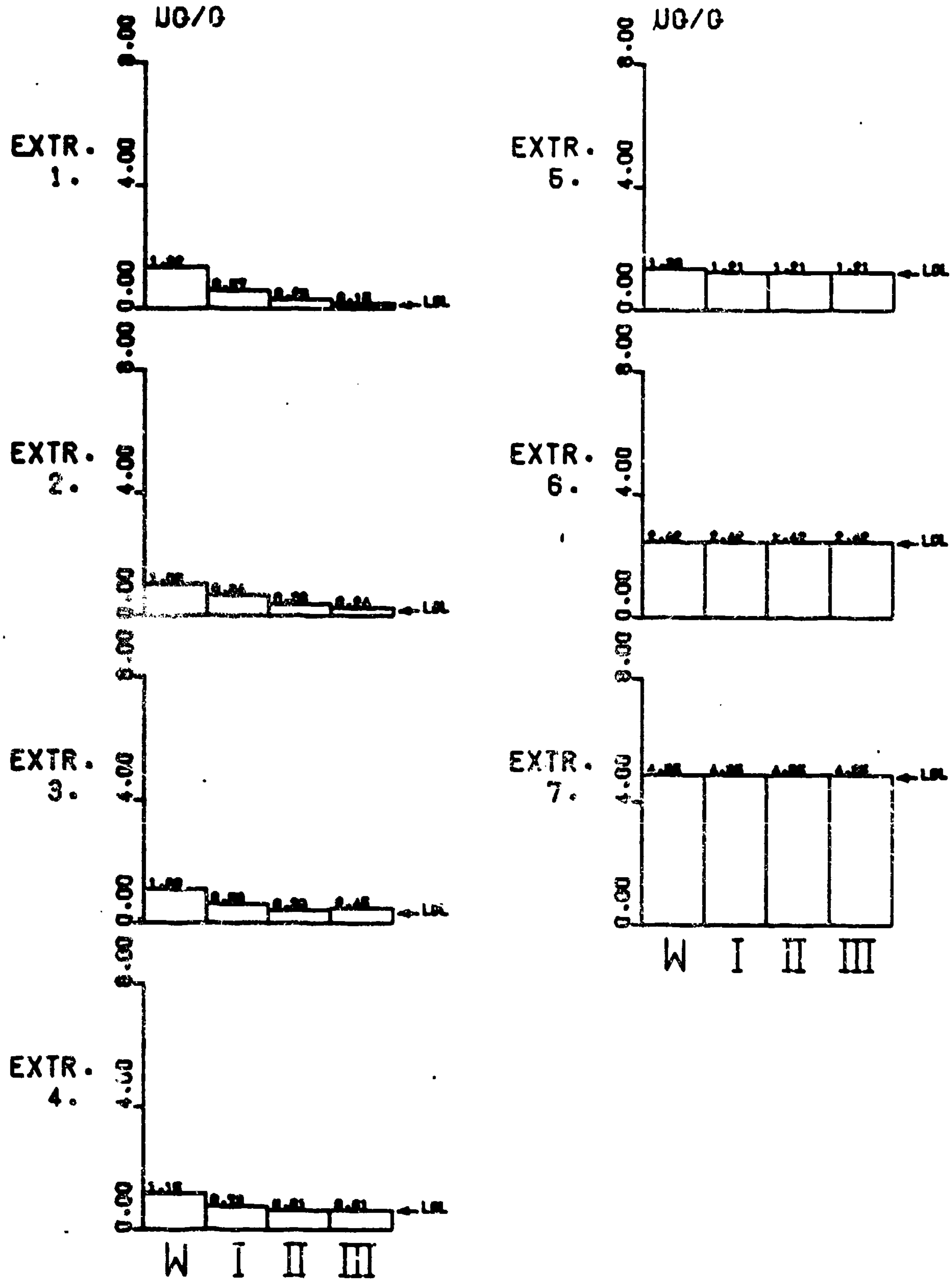
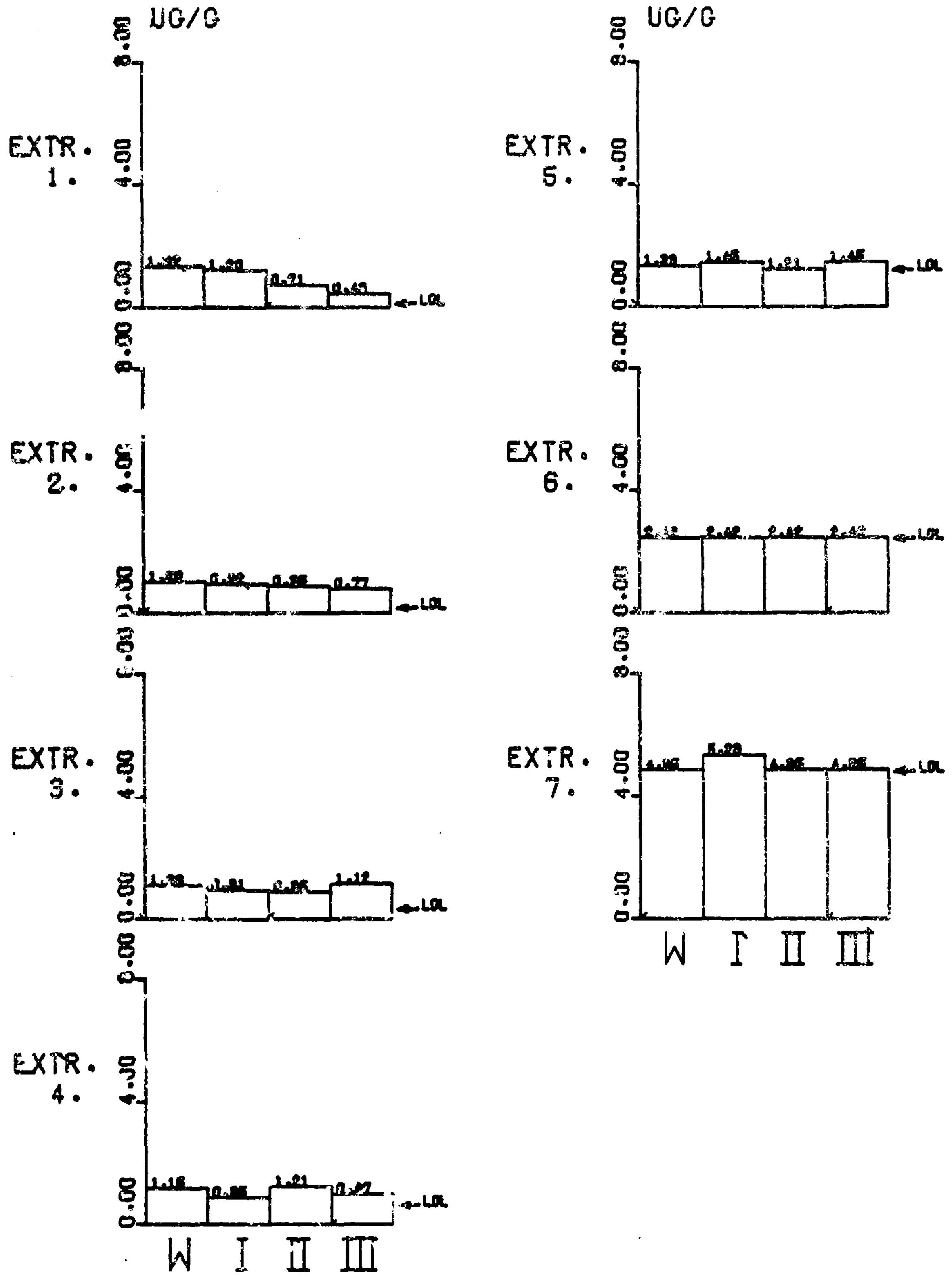


FIGURE 134. WEIGHT OF NICKEL FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

TABLE 70. NICKEL FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.66	1.32										
	I	.60	1.20	.12	1.32	.12	.09	.09	.91	13.16	85.66	.10	5.76
	II	.35	.71	.49	1.20	.49	.41	.41	.59	22.71	87.50	.70	34.99
	III	.22	.43	.27	.71	.27	.39	.39	.61	36.78	88.44	.63	32.13
	I+II			.31	.66	.31	.47	.47	.53	89.70	89.36	.87	41.07
	I+II+III			.30	.44	.30	.67	.67	.33	327.40	89.82	2.05	63.96
2	W	.33	1.00										
	I	.31	.92	.08	2.32	.20	.08	.08	.92	17.20	86.67	.21	12.03
	II	.28	.85	.08	2.13	.57	.08	.27	.92	19.18	87.02	.67	33.93
	III	.26	.77	.08	1.56	.35	.09	.22	.91	20.77	87.24	.45	24.27
	I+II			.08	1.16	.38	.15	.33	.85	74.93	89.24	.90	42.14
	I+II+III			.08	.77	.37	.23	.48	.77	184.32	89.69	1.46	55.30
3	W	.18	1.06										
	I	.15	.91	.15	3.30	.35	.14	.10	.86	17.66	86.76	.38	20.97
	II	.14	.85	.06	3.04	.63	.07	.21	.93	19.25	87.03	.74	36.65
	III	.19	1.12	-.27	2.40	.08	-.32	.03	1.32	14.07	85.94	.07	3.87
	I+II			.11	1.69	.49	.20	.29	.80	75.18	89.24	1.15	49.11
	I+II+III			-.02	1.13	.35	-.06	.31	1.06	126.98	89.55	.94	43.27
4	W	.10	1.15										
	I	.07	.85	.30	4.53	.65	.26	.14	.74	19.27	87.03	.77	37.52
	II	.10	1.21	-.36	3.08	.27	-.43	.07	1.43	13.17	85.66	.22	12.45
	III	.08	.97	.24	3.62	.32	.20	.09	.80	16.52	86.54	.33	18.17
	I+II			-.03	2.27	.46	-.05	.20	1.05	52.57	88.91	.76	37.17
	I+II+III			.06	1.51	.41	.16	.27	.84	147.01	89.61	1.28	51.92
5	W	.06	1.33										
	I	.06	1.45	-.12	5.87	.53	-.09	.09	1.09	11.16	84.88	.36	20.03
	II	<.05	<1.21	.24	5.34	.51	.17	.10	.83	13.37	85.72	.42	22.82
	III	.06	1.45	-.24	4.83	.08	-.20	.02	1.20	10.85	84.73	.05	2.98
	I+II			.06	2.93	.52	.09	.18	.91	52.67	88.91	.86	40.64
	I+II+III			-.04	1.96	.37	-.09	.19	1.09	97.92	89.41	.77	37.50
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	.06	5.33										
	II	.05	4.85										
	III	.05	4.85										
	I+II												
	I+II+III												



-'GURE 135. WEIGHT OF NICKEL FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

TABLE 71. NICKEL FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.66	1.32										
	I	.40	.80	.53	1.32	.53	.40	.40	.60	31.24	88.17	.66	33.35
	II	.20	.40	.39	.80	.39	.49	.49	.51	61.37	89.07	.97	44.27
	III	.17	.33	.07	.40	.07	.18	.18	.82	73.42	89.22	.21	11.98
	I+II			.46	.66	.46	.69	.69	.31	243.86	89.77	2.28	66.27
	I+II+III			.33	.44	.33	.75	.75	.25	661.84	89.91	2.97	71.39
2	W	.33	1.00										
	I	.25	.76	.24	2.32	.77	.24	.33	.76	33.22	88.28	1.01	45.38
	II	.17	.50	.26	1.56	.65	.34	.42	.66	50.11	88.86	1.30	52.50
	III	.13	.39	.11	.90	.10	.21	.20	.79	62.39	89.08	.45	24.17
	I+II			.25	1.16	.71	.50	.61	.50	198.06	89.71	2.04	70.59
	I+II+III			.20	.77	.53	.61	.69	.39	561.55	89.90	4.05	76.13
3	W	.10	1.06										
	I	.12	.70	.36	3.38	1.13	.34	.33	.66	36.64	88.44	1.62	58.36
	II	.11	.64	.06	2.25	.71	.09	.32	.91	39.47	88.55	1.12	48.22
	III	.07	.42	.21	1.54	.39	.33	.25	.67	58.44	89.02	.92	42.51
	I+II			.21	1.69	.92	.40	.54	.60	156.28	89.63	2.90	70.96
	I+II+III			.21	1.13	.74	.60	.66	.40	522.94	89.89	5.26	79.24
4	W	.10	1.15										
	I	.07	.79	.36	4.53	1.49	.32	.33	.68	32.87	88.26	1.90	62.21
	II	<.05	<.61	.18	3.04	.89	.23	.29	.77	41.74	88.63	1.48	55.86
	III	.06	.67	-.06	2.15	.33	-.10	.15	1.10	37.10	88.46	.49	26.22
	I+II			.27	2.27	1.19	.47	.53	.53	165.00	89.65	3.94	75.76
	I+II+III			.16	1.51	.91	.42	.60	.58	333.51	89.83	4.08	76.21
5	W	.06	1.33										
	I	.06	1.33	.00	5.87	1.49	.00	.25	1.00	19.42	87.05	1.12	48.27
	II	.06	1.33	.00	4.37	.89	.00	.20	1.00	18.97	86.98	.67	33.84
	III	<.05	<1.21	.12	3.48	.45	.09	.13	.91	20.50	87.21	.37	20.35
	I+II			.00	2.93	1.19	.00	.41	1.00	75.00	89.24	1.79	60.83
	I+II+III			.04	1.96	.95	.09	.48	.91	183.53	89.69	2.34	66.88
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

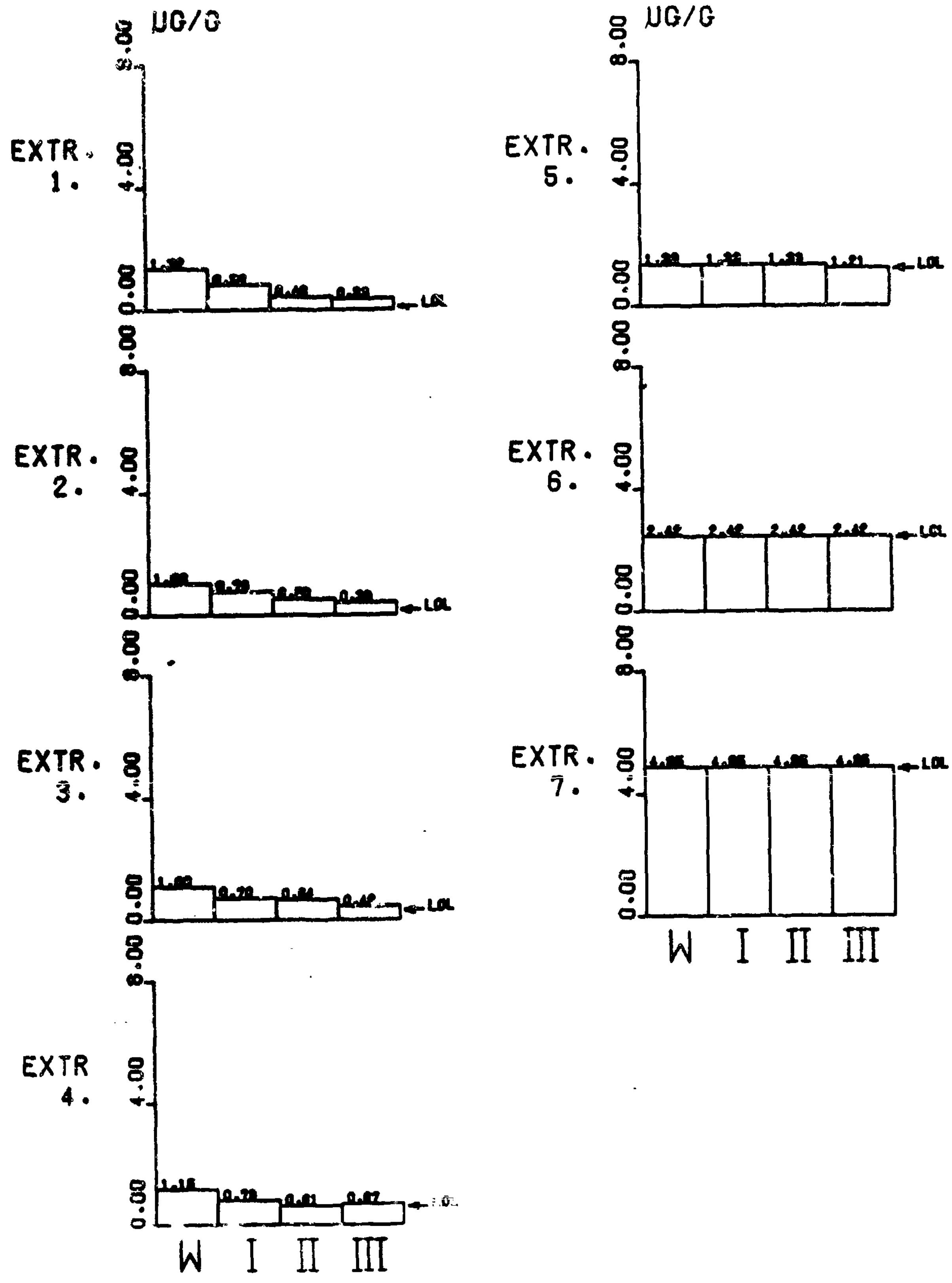


FIGURE 136. WEIGHT OF NICKEL FROM ZINC SECONDARY REFINING SLUDGE ON NICHOLSON SOIL

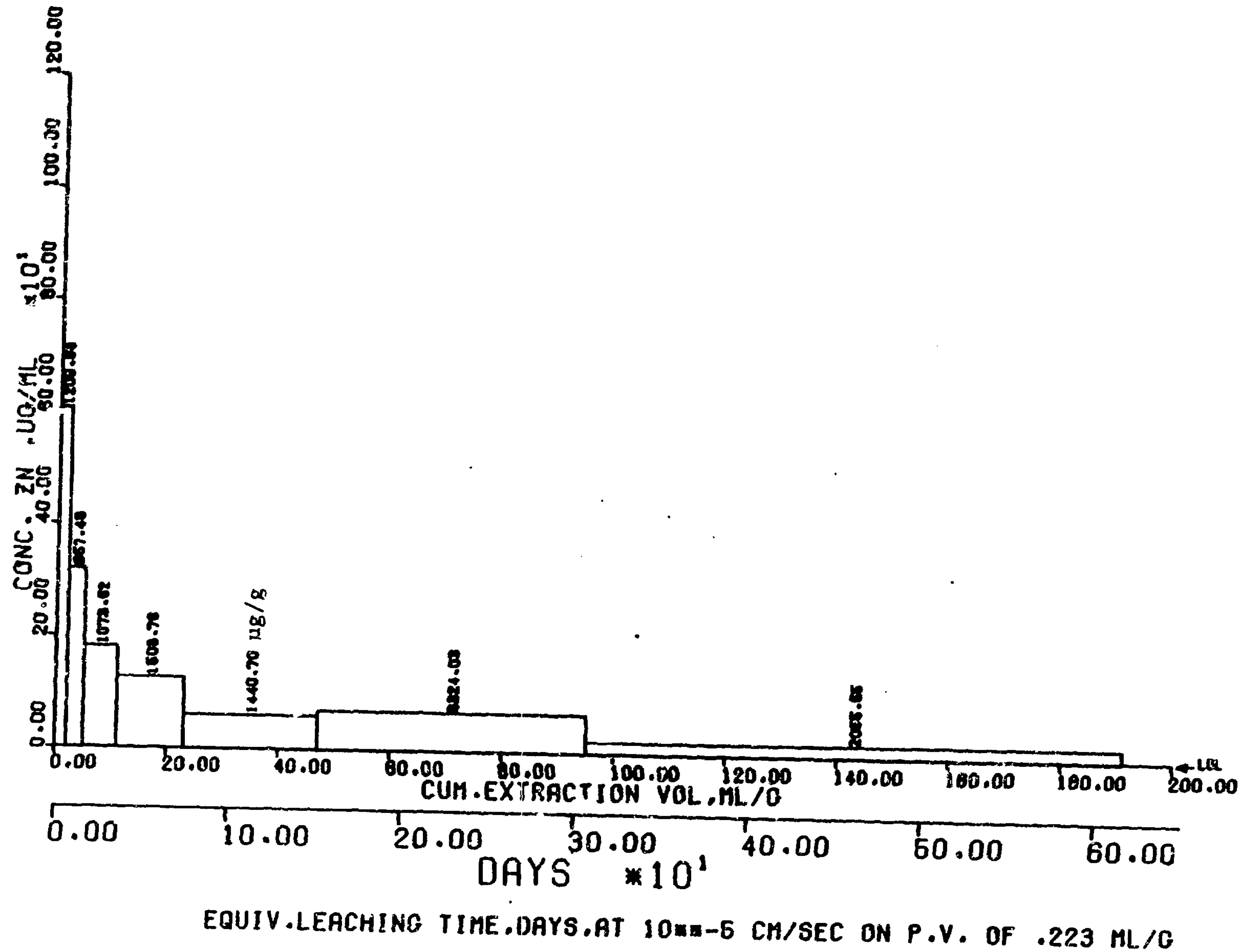


FIGURE 137. EXTRACTION OF ZINC FROM ZINC SECONDARY-REFINING SLUDGE.

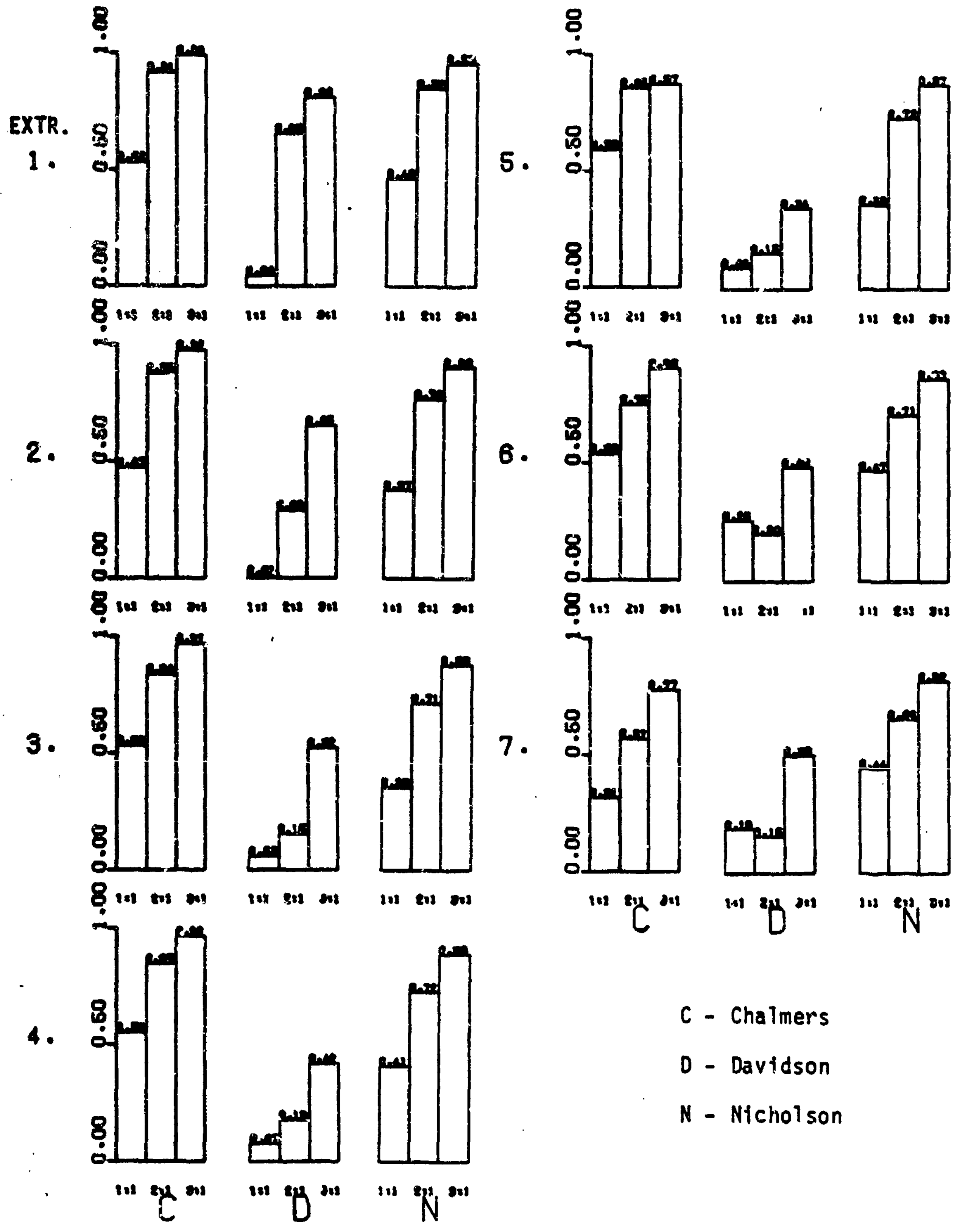


FIGURE 138. COMPARING FRACTION ZINC RETAINED BY SOILS FROM ZINC SECONDARY-REFINING SLUDGE LEACHATE.

TABLE 72. ZINC FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	604.99	1209.98										
	I	285.33	570.65	639.33	1209.90	639.33	.53	.53	.47	1.23	50.86	1.12	48.25
	II	51.71	103.42	467.23	570.65	467.23	.82	.82	.18	5.12	78.94	4.52	77.52
	III	7.27	14.54	88.88	103.42	88.88	.86	.86	.14	10.36	84.49	6.11	80.71
	I+II			553.28	604.99	553.28	.91	.91	.09	13.09	85.63	10.70	84.66
	I+II+III			398.48	403.33	398.48	.99	.99	.01	120.44	89.52	82.19	89.30
2	W	319.16	957.48										
	I	191.39	574.18	383.30	2167.46	1022.63	.40	.47	.60	1.89	62.10	1.78	60.69
	II	54.74	164.23	409.96	1144.83	877.18	.71	.77	.29	5.72	80.08	5.34	79.40
	III	14.24	42.72	121.50	267.65	210.38	.74	.79	.26	6.37	81.08	4.92	78.52
	I+II			396.63	1083.73	949.91	.83	.88	.17	13.07	85.63	11.57	85.06
	I+II+III			384.92	722.49	703.40	.96	.97	.04	62.41	89.08	49.39	88.84
3	W	170.94	1073.62										
	I	63.78	382.69	690.93	3241.00	1713.56	.64	.53	.36	4.64	77.84	4.48	77.41
	II	43.38	260.28	122.41	1527.52	999.60	.32	.65	.68	4.08	76.22	3.84	75.41
	III	8.08	48.48	211.80	527.93	422.18	.81	.80	.19	9.98	84.28	8.71	83.45
	I+II			486.67	1620.54	1356.58	.76	.84	.24	11.37	84.98	10.42	84.52
	I+II+III			341.71	1000.36	1045.11	.95	.97	.05	76.15	89.25	64.67	89.11
4	W	125.73	1503.76										
	I	50.95	611.45	897.30	4749.84	2610.86	.59	.55	.41	4.37	77.11	4.27	76.82
	II	16.41	196.95	414.50	2138.90	1414.10	.68	.66	.32	7.49	82.40	7.18	82.07
	III	5.61	67.27	129.68	724.00	551.86	.66	.76	.34	9.12	83.74	8.20	83.05
	I+II			655.90	2374.92	2012.48	.87	.85	.13	21.69	87.36	20.44	87.20
	I+II+III			480.50	1583.28	1525.61	.96	.96	.04	76.31	89.25	68.04	89.16
5	W	60.03	1440.70										
	I	17.37	416.93	1023.78	6190.54	3634.64	.71	.59	.29	8.87	83.56	8.72	83.46
	II	7.68	184.22	232.70	2555.91	1646.81	.56	.64	.44	9.27	83.85	8.94	83.62
	III	26.61	638.72	-454.50	909.10	97.36	-2.47	.11	3.47	.25	13.99	.15	8.67
	I+II			628.24	3095.27	2640.72	.87	.85	.13	30.01	88.09	28.67	88.00
	I+II+III			267.33	2063.51	1792.94	.56	.87	.44	9.29	83.86	8.42	83.23
6	W	69.25	3324.03										
	I	38.94	1868.90	1455.13	9514.57	5089.76	.44	.53	.56	2.76	70.06	2.72	69.84
	II	31.31	1502.88	366.02	4424.81	2012.83	.20	.45	.80	1.38	54.08	1.34	53.25
	III	2.83	135.74	1367.14	2411.98	1464.50	.91	.61	.09	11.24	84.92	10.79	84.70
	I+II			910.58	4757.29	3551.30	.55	.75	.45	4.89	78.44	4.73	78.05
	I+II+III			1062.76	3171.52	2855.70	.96	.90	.04	67.21	89.15	63.11	89.09
7	W	21.41	2055.55										
	I	36.66	3519.65	-1464.1	11570.13	3625.67	-.71	.31	1.71	1.05	46.33	1.03	45.85
	II	27.27	2617.92	901.73	7944.46	2914.56	.26	.37	.74	1.14	48.67	1.11	48.07
	III	17.27	1658.02	959.90	5029.90	2424.40	.37	.48	.63	1.50	56.30	1.46	55.63
	I+II			-281.18	5785.06	3270.11	-.27	.57	1.27	2.59	68.91	2.50	68.18
	I+II+III			132.51	3856.71	2988.21	.19	.77	.81	5.74	80.12	5.41	79.52

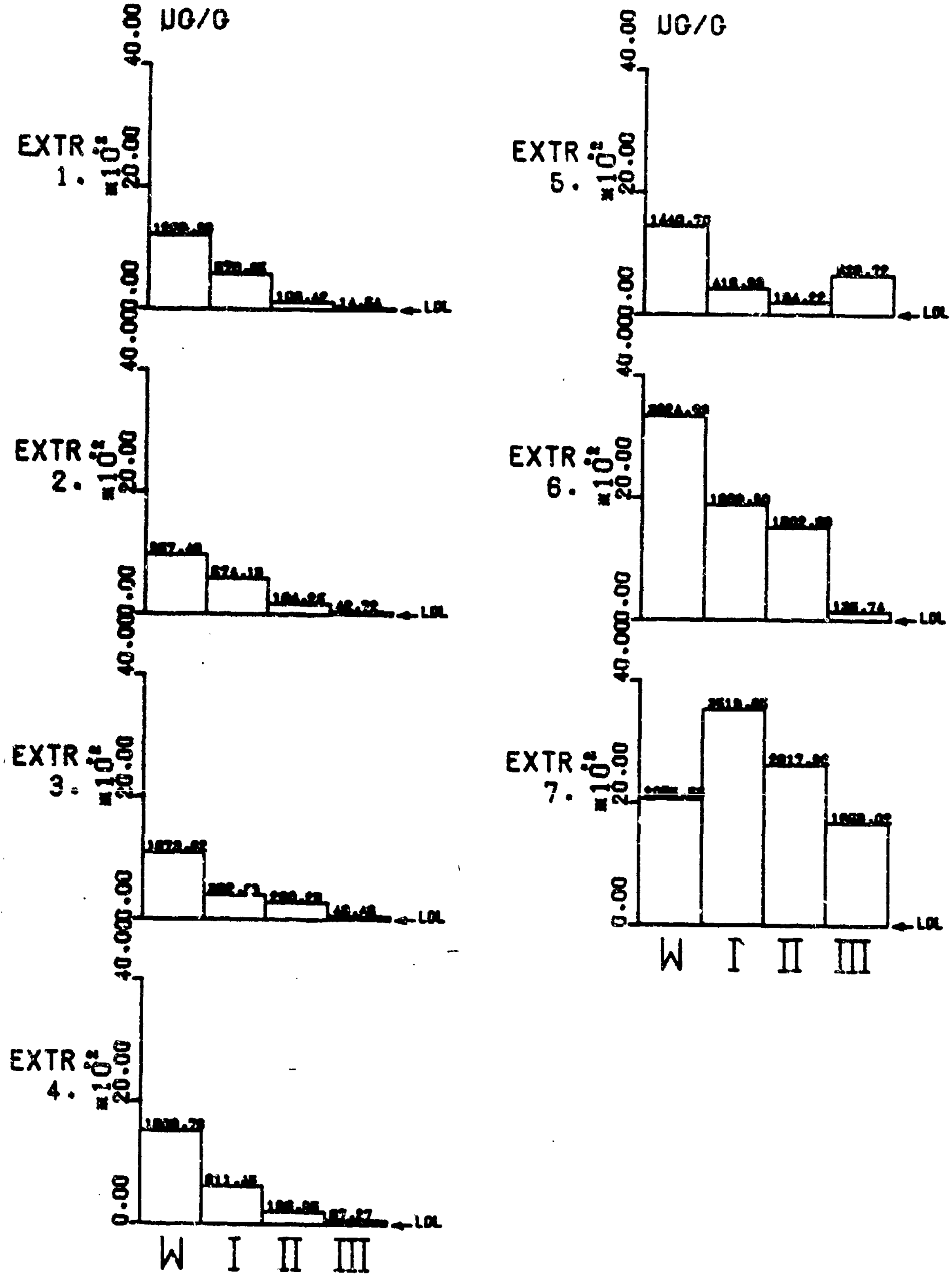


FIGURE 139. WEIGHT OF ZINC FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL.

TABLE 73. ZINC FROM ZINC SFCONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	404.99	1209.98										
	I	578.73	1157.46	52.52	1209.98	52.52	.04	.04	.96	.09	5.31	.05	2.60
	II	211.60	423.19	734.27	1157.46	734.27	.63	.63	.37	1.87	61.80	1.74	60.04
	III	118.17	236.34	186.85	423.19	186.85	.44	44	.56	1.02	45.66	.79	38.33
	I+II			393.40	604.59	393.40	.65	.65	.35	2.38	67.20	1.86	61.73
	I+II+III			324.55	403.33	324.55	.80	.80	.20	6.21	80.86	4.12	76.36
2	W	319.16	957.48										
	I	329.77	989.30	-31.82	2157.46	20.70	-.03	.01	1.03	.08	4.38	.02	1.20
	II	373.70	1121.10	-131.81	2146.75	602.46	-.13	.28	1.13	.59	30.39	.54	28.25
	III	174.73	524.19	596.91	1544.29	783.76	.53	.51	.47	1.60	58.00	1.50	56.22
	I+II			-81.81	1078.73	311.58	-.17	.29	1.17	.75	36.95	.56	29.07
	I+II+III			144.43	722.49	468.90	.45	.65	.55	3.63	74.59	2.60	69.57
3	W	170.94	1073.62										
	I	150.99	905.97	167.65	3241.08	188.35	.16	.06	.84	.27	15.04	.21	11.74
	II	200.99	1205.94	-299.97	3052.73	302.49	-.33	.10	1.33	.30	16.51	.25	14.08
	III	132.82	796.89	409.05	2750.23	1192.81	.34	.43	.66	1.57	57.44	1.50	56.25
	I+II			-66.16	1620.54	245.42	-.12	.15	1.12	.59	30.52	.41	22.15
	I+II+III			92.24	1080.36	561.22	.26	.52	.74	2.73	69.91	2.11	64.67
4	W	125.73	1508.76										
	I	111.86	1342.29	166.47	4749.84	354.82	.11	.07	.89	.31	16.98	.26	14.81
	II	96.96	1163.52	178.77	4395.02	481.27	.13	.11	.87	.46	24.74	.41	22.47
	III	100.85	1210.18	-46.64	3913.75	1146.15	-.04	.29	1.04	.99	44.79	.95	43.44
	I+II			172.62	2374.92	418.04	.23	.18	.77	.91	42.23	.72	35.70
	I+II+III			99.53	1583.28	660.75	.20	.42	.80	2.05	63.96	1.64	58.60
5	W	60.03	1440.70										
	I	52.32	1255.63	105.07	6190.54	559.90	.13	.09	.87	.47	25.35	.43	23.27
	II	56.00	1344.11	-80.48	5650.65	392.79	-.07	.07	1.07	.33	18.43	.29	16.29
	III	53.93	1294.42	49.69	5257.86	1195.84	.04	.23	.96	.97	44.02	.92	42.73
	I+II			40.30	3095.27	466.34	.07	.15	.93	.86	40.62	.69	34.76
	I+II+III			40.76	2063.51	709.51	.10	.34	.90	2.03	63.74	1.64	58.70
6	W	69.25	3324.03										
	I	29.38	1410.28	1913.75	9514.57	2453.64	.58	.26	.42	1.78	60.66	1.74	60.11
	II	49.64	2382.79	-972.51	7060.93	-579.72	-.69	-.08	1.69	-.22	-12.42	-.24	-13.67
	III	17.73	850.82	1531.97	7640.65	2727.81	.64	.36	.36	3.27	73.00	3.21	72.68
	I+II			470.62	4757.29	936.96	.28	.20	.72	.88	41.31	.79	38.18
	I+II+III			824.40	3171.52	1533.91	.74	.48	.26	5.99	80.52	5.41	79.52
7	W	21.41	2055.55										
	I	24.44	2346.43	-290.88	11570.13	2162.76	-.14	.19	1.14	.95	43.39	.92	42.67
	II	22.32	2142.82	203.62	9407.36	-376.10	.09	-.04	.91	-.15	-8.52	-.18	-9.96
	III	9.04	867.77	1275.02	9783.47	4002.83	.60	.41	.40	4.68	77.93	4.61	77.77
	I+II			-43.63	5785.06	893.33	-.04	.15	1.04	.94	43.12	.83	39.02
	I+II+III			395.72	3856.71	1929.83	.58	.50	.42	7.24	82.14	5.67	81.48

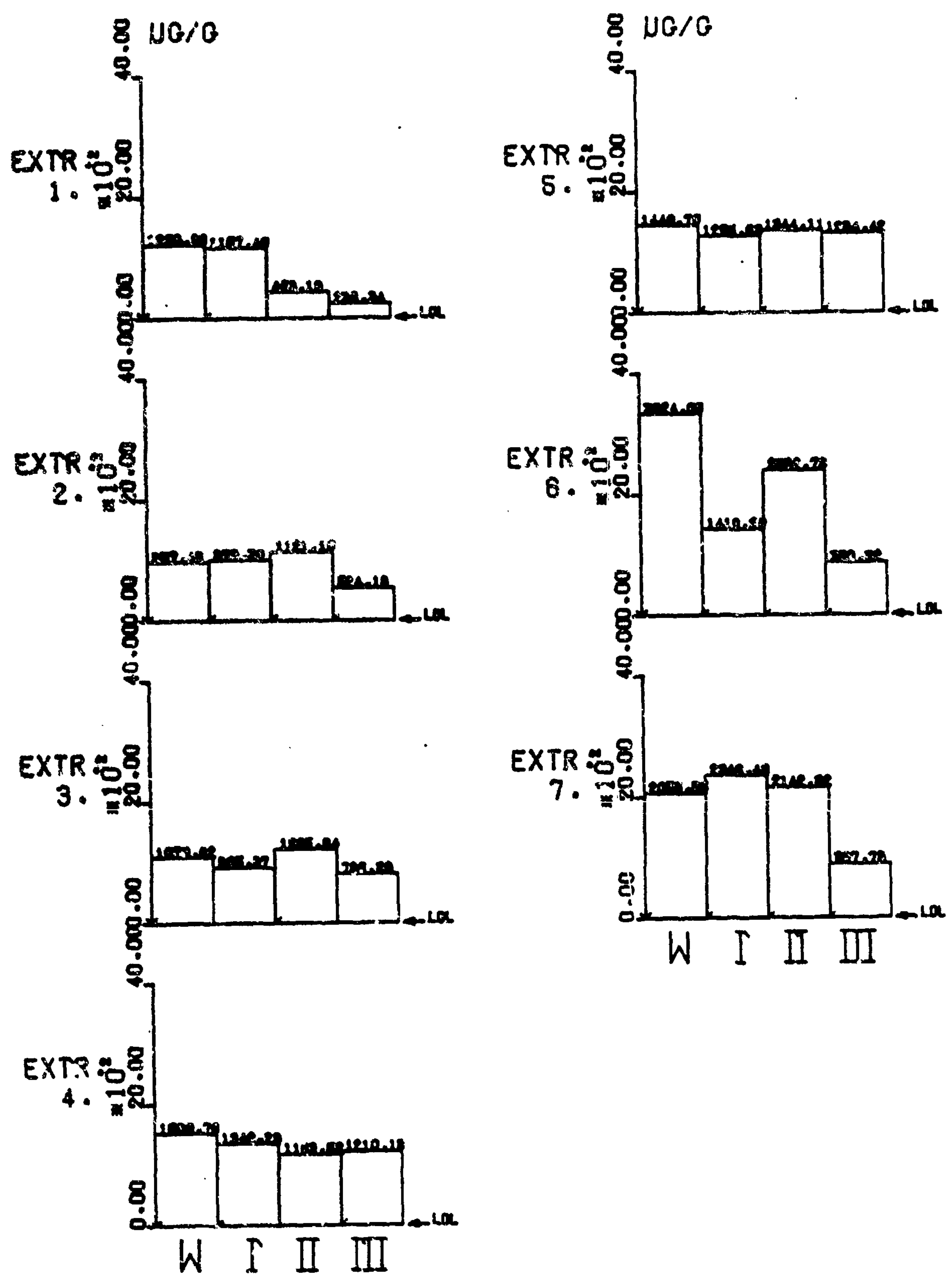


FIGURE 140. WEIGHT OF ZINC FROM ZINC SECONDARY-REFINING SLUDGE ON DAVIDSON SOIL.

TABLE 74. ZINC FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	604.95	1209.90										
	I	327.24	654.48	555.50	1209.90	555.50	.46	.46	.54	.96	43.92	.85	40.32
	II	93.46	186.85	467.63	654.48	467.63	.71	.71	.29	2.90	70.99	2.50	68.22
	III	28.84	57.67	129.18	186.85	129.18	.69	.69	.31	3.54	74.21	2.24	65.94
	I+II			511.57	644.99	511.57	.85	.85	.15	7.83	81.96	5.48	79.65
	I+II+III			384.10	403.33	384.10	.95	.95	.05	31.65	88.19	19.58	87.13
2	W	319.16	957.48										
	I	233.82	701.45	256.03	2167.44	811.53	.27	.37	.73	1.26	51.64	1.16	49.16
	II	107.42	322.55	378.60	1355.93	846.23	.54	.62	.46	2.85	70.68	2.62	69.12
	III	52.47	157.41	165.44	589.70	294.62	.51	.58	.49	2.35	66.92	1.87	61.89
	I+II			327.32	1085.73	828.88	.66	.76	.34	6.06	80.63	5.13	78.98
	I+II+III			266.69	722.49	650.79	.84	.98	.16	16.68	86.57	12.40	85.39
3	W	178.94	1073.62										
	I	124.23	745.38	326.24	3241.08	1139.77	.31	.35	.69	1.63	58.46	1.53	56.82
	II	70.14	405.87	324.51	2101.31	1170.74	.44	.56	.56	2.96	71.33	2.78	70.23
	III	31.56	189.38	231.49	730.56	526.11	.55	.57	.45	3.17	72.51	2.78	70.20
	I+II			326.38	1620.54	1155.26	.61	.71	.39	6.20	80.84	5.49	79.68
	I+II+III			294.75	1000.36	945.54	.82	.88	.18	16.53	86.91	14.98	86.18
4	W	125.73	1508.76										
	I	59.74	716.98	791.86	4749.84	1931.64	.52	.41	.48	2.30	70.34	2.69	69.64
	II	31.36	376.33	340.57	2818.20	1511.31	.48	.54	.52	4.21	76.65	4.02	76.02
	III	11.46	137.56	238.76	1306.89	764.87	.63	.59	.37	6.10	80.70	5.56	79.80
	I+II			566.22	2374.92	1721.47	.75	.72	.25	9.94	84.26	9.15	83.76
	I+II+III			457.07	1583.28	1402.61	.91	.89	.09	35.40	88.39	30.59	88.13
5	W	66.83	448.78										
	I	40.58	165.94	274.76	6190.54	2286.40	.19	.36	.81	1.96	62.93	1.89	62.15
	II	16.86	370.86	775.60	3984.15	2286.99	.67	.57	.33	6.05	80.62	5.86	80.32
	III	11.66	265.43	124.84	1697.15	889.71	.32	.52	.68	3.63	74.61	3.35	73.39
	I+II			525.22	3395.27	2246.69	.73	.73	.27	12.28	85.34	11.51	85.04
	I+II+III			391.76	2043.51	1794.37	.82	.87	.18	22.92	87.49	20.28	87.18
6	W	69.25	3324.03										
	I	22.22	1064.56	2257.47	9514.57	4463.87	.68	.47	.32	4.26	76.78	4.19	76.56
	II	22.03	1055.65	-29.09	5850.71	2257.91	-.03	.45	1.03	2.13	64.84	2.06	64.12
	III	10.45	501.77	593.88	2792.80	1483.59	.54	.53	.46	3.11	72.15	2.96	71.31
	I+II			1114.19	4757.29	3360.89	.67	.71	.33	6.41	81.13	6.13	80.74
	I+II+III			948.75	3171.52	2735.12	.85	.86	.15	17.69	86.77	16.35	86.50
7	W	21.41	2055.55										
	I	14.39	1381.68	673.07	11570.13	5137.74	.33	.44	.67	3.77	75.15	3.72	74.95
	II	12.37	1187.76	193.92	6432.39	2451.83	.14	.38	.86	2.13	64.82	2.06	64.15
	III	8.18	785.30	402.38	3980.56	1885.97	.34	.47	.66	2.50	68.17	2.40	67.39
	I+II			433.90	5785.04	3794.70	.42	.66	.58	6.64	81.44	6.39	81.11
	I+II+III			423.39	3856.71	3158.51	.62	.52	.38	12.72	85.57	12.06	85.26

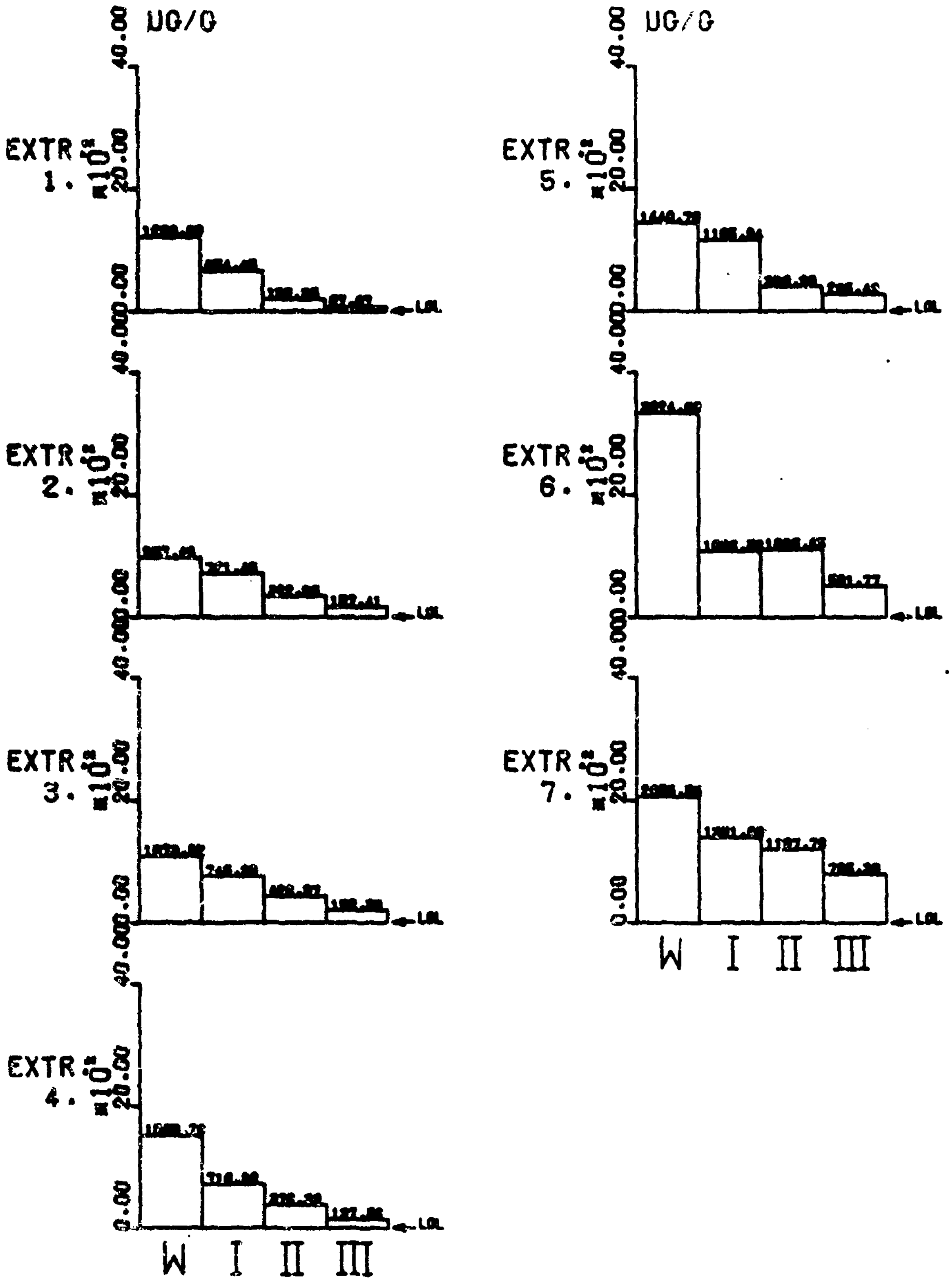


FIGURE 141. WEIGHT OF ZINC FROM ZINC SECONDARY-REFINING SLUDGE ON NICHOLSON SOIL.

OIL RE-REFINING WASTE

Even though oil is less dense than water, it was not known whether water falling on an oily residue in a pond would find its way down through the waste and relatively efficiently extract the water-soluble components. The water instead may extract mainly at the upper surface, perhaps moving horizontally as run-off to soak into the adjacent soil. To obtain an estimate of the difference in extractability of water-soluble components under extremes of conditions, two extraction techniques were applied. One portion of oil re-refining waste was extracted by vigorous shaking, such that a suspension of tarry curds in water resulted. The other sample of waste was shaken more gently with water, so that the two phases remained more as layers. (Both mixtures were readily filterable with vacuum.) These two series of extractions were used to challenge separate sets of soil batches. They were not run in duplicate, so the data does not represent averages. The first, vigorously shaken waste is designated as A in the discussion to follow, and the second, layered waste and water is labeled B.

This oil re-refining residue was an extremely strong emitter of what seemed to be sulfur trioxide fumes so the work was performed in a fume hood. Although the extractions were conducted in closed containers, the filtrations were performed using vacuum and no attempt was made to quantitate the amount of gaseous pollution. Only that which was extracted by water was detected, and then just by its contribution to the acidity and conductivity.

Water which had been vigorously shaken with this oil waste (Table 75, Figures 142 to 147) was strongly acid (pH 0.9) and had a very high conductance. The less well mixed sample (Table 76, Figures 193 to 198) had a conductance in the initial extract that was lower by a factor of 2.7 and a pH that corresponded to a hydrogen ion concentration that was less by a factor of 2.5. (This can be calculated from the pH's: 1.3 -0.9 = 0.4; antilog 0.4 = 2.5.) However, as will be seen to be the case with many of the elements discussed below, the conductances indicated that the cumulative sum of the microequivalents of dissolved ions was comparable for both extraction techniques by the end of the seventh extraction.

TABLE 75. LEACHABILITY OF OIL RE-REFINING WASTE EXTRACTED BY METHOD A.

Element	Initial Conc. (μg/ml)	When Concentration Levels Off: Conc. (μg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days	Total Weight Extracted (μg/g waste)	Percentage Extracted
Be	0.01	0.01	7	190	620	1.9	-
B	20.	1.1	3	11	36	59.	≈100.
Cd	1.5	0.01(LDL)	6	95	308	5.9	≈100.
Cr	5.0	0.01(LDL)	5	47	150	16.	44.
Cu	3.0	1.0	2	5	16	9.1	16.
Pb	4.9	1.3	7	190	620	368.	16.
Ni	1.4	0.08	3	11	36	4.0	>100.
Ti	0.91	0.12	3	11	36	3.6	≈100.
Zn	913.	0.23	7	190	620	2740.	>>100.

Measurement	Initial	Final	Estim.Tot.Extr. (μ equiv/g)
Conduct. (μ mho)	333,000.	125.	12,000.
pH	0.9	4.0	

TABLE 76. LEACHABILITY OF OIL RE-REFINING WASTE EXTRACTED BY METHOD B.

Element	Initial Conc. (μg/ml)	When Concentration Levels Off: Conc. (μg/ml)	Extr. Nr.	Extr.Vol. (ml/g)	Equiv. Days	Total Weight Extracted (μg/g waste)	Percentage Extracted
Be	0.01	0.01	7	190	620	1.9	-
B	4.0	0.50(LDL)	5	47	150	44.	≈100.
Cd	0.37	0.01(LDL)	6	95	308	4.8	≈100.
Cr	0.70	0.01(LDL)	5	47	150	11.	30.
Cu	1.0	0.01(LDL)	2	5	16	8.1	14.
Pb	5.4	8.0	7	190	620	1131.	48.
Ni	0.24	0.06	4	23	75	3.2	≈100.
Ti	0.14	0.35	3	11	36	2.7	≈ 90.
Zn	155.	1.74	7	190	620	2204.	>>100.

Measurement	Initial	Final	Estim.Tot.Extr. (μ equiv/g)
Conduct. (μ mho)	125,000.	667.	13,800.
pH	1.3	3.1	

Beryllium

Tables 75 and 76, and Figures 148 and 199 show that both extraction techniques leached beryllium out of oil re-refining waste at the same, extremely low concentration level (0.01 μg/ml). A total of 1.9 μg/g was extracted by water in the parallel sequences of seven extractions. However, the difference between the two extraction techniques caused a difference in pH and concentration of dissolved materials which significantly affected how much beryllium emerged from the soils. (The minus signs of the Cumulative Total Retained column of Tables 77, 78, 79, and 104, 105, 106 mean that the soils were giving up that amount of beryllium. This is also seen in Figures 150, 151, 152, and 201, 202, 203.) Table 77, for instance, shows that by the fourth extraction using method A, the amount of beryllium displaced from Chalmers soil had reached a maximum such that the solution challenging soil batch I caused the loss of 1.10 μg/g which is 48 percent of the 2.30 μg/g originally on the unexposed Chalmers soil (Table 5), the solution exiting soil batch I caused 1.27 μg/g or 53 percent to leave soil section II, and the resulting solution left soil section III with 1.45 μg/g or 63 percent of the soil's beryllium. Davidson soil lost 65 percent as much beryllium as Chalmers soil did in the seven extractions by method A, and Nicholson soil lost 124 percent as much as Chalmers soil. The higher pH and lower conductivity of the solution from extraction method B caused the loss of less beryllium from the soil, from 59 to 82 percent as much as was observed for set A. (Set B on Chalmers soil suffered a mishap after the first extraction, so the remainder of that data is not available.)

The fact that the aqueous extract of this oil re-refining waste was a powerful displacer of beryllium from these soils is further shown by the large minus values given for all three soil-to-waste ratios in Figures 149 and 200.

Boron

Boron was extracted out of this waste by method A to yield a solution of moderately low concentration (20 μg/ml) and it dropped to the detection limit by the fourth extraction. A total of 59 μg/g, or approximately 100 percent of the boron in the waste (refer to Table 11) was extracted this way (Tables 75 and 153). Method B yielded only 4 μg/ml in the first extract but by the fifth extract a total of 44 μg/g was removed, which is 75 percent of method A (Table 76 and Figure 204).

The three soils behaved very similarly, as seen in Figures 154 to 157 and Tables 80 to 82 for method A. Although an average of 84 percent of the boron was removed from the solution in the first extraction, the ability of the soils to remove boron dropped rapidly and by the third extraction only 59 percent of the cumulative challenge was retained at a 3:1 soil-to-waste ratio. The penetration factors larger than 1.00 show that by the second extraction the soils were beginning to give up more boron than was in the solution challenging that batch.

A similar pattern is seen in the samples of set B. Figures 205 to 208 and Tables 107 to 109 show that 77 percent of the boron was removed from the

first extract of the composition produced by extraction method B. By the fourth extraction, 57 percent of the cumulative challenge was being retained.

Cadmium

Tables 75, 83, to 85, and Figure 158 show that cadmium was found at a moderate concentration in the first extract from this waste (1.52 μg/ml) but the output dropped rapidly, reaching the detection limit in the sixth extraction by method A. A total of 5.9 μg/g was extracted, which is approximately 100 percent of the cadmium in the waste. Extraction method B produced a solution which was 24 percent as concentrated (0.37 μg/ml) and a total of 4.8 mg/g was extracted from the waste, as seen in Figure 209 and Tables 76, 110 to 112.

The composition of these extracts soon caused all three soils to give up their cadmium (Figures 159 to 162 and 210 to 213). The solutions resuting from challenging the soils with the first two method A extracts contained moderate concentrations of cadmium (100 to 200 times the SDWS) and by the time the solutions dropped to the lower detection limit, the analysis indicated (by the magnitude of the negative values in the cumulative total retained column and the appearance of negative distribution coefficients calculated including soil) that more cadmium had been removed from the soil than it had originally contained . (This indicates the possibility of analytical enhancement by the sample matrix. No true blank could be made. This problem could be studied by the method of additions.) When the soils were challenged by the first two method B extracts, moderately low concentrations of cadmium (20 to 50 times the SWDS) were observed in the resulting solutions.

Chromium

A moderate concentration of chromium (5 μg/ml) was found in the initial extraction by method A, but it fell to the detection limit (0.01 μg/ml) with the fifth extraction. A total of 16 μg/g was extracted, which is 44 percent of the total present in the waste. (Table 75 and Figure 163.) Method B removed only low concentrations of chromium (1.1 μg/ml and below) yielding a total of 11 μg/g, which is 30 percent of the amount in the waste (Table 76 and Figure 214).

The challenge to the soils (W) was always less than the output, showing that the composition of the extracts caused release of chromium from the soils. The solution from method A caused Chalmers soil to lose about twice as much chromium as Davidson and Nicholson soils (Tables 86 and 88 and Figures 164 to 167). The cumulative effect of five extractions by method B resulted in Nicholson soil losing more than Davidson soil. After this, the soil effluents dropped below the detection limit (Tables 113 to 115 and Figures 215 to 218).

Copper

Tables 75 and 76, and Figures 168 and 219 show that copper was eluted in very low concentrations (3.0 μg/ml and below), giving a total of 9.1 μg/g by method A, which is 16 percent of the copper present in the waste, and 8.1 μg/g (14 percent) by method B. Figures 169 and 172 and 220 to 223, together

with Tables 89 to 91, and 116 to 118 show that considerably more copper was displaced from the soil than was present in the series of waste extracts: changing the sign of the Fraction Retained Total Challenge column and adding 1.00 reveals that 6.4 to 10.7 times as much was flushed off by the three method A solutions, and 4.0 to 6.5 times as much was removed from the soil by three method B extracts, as was present in the sol ions challenging the soils at a 3:1 soil-to-waste ratio.

Lead

Moderate concentrations of lead (up to 8 μg/ml) persisted in the waste extracts obtained by both methods (Tables 75 and 76, and Figures 173 and 224). Totals of 368 and 1131 μg/g were extracted by methods A and B, respectively, which is 16 to 46 percent of the total present in the waste. The results were somewhat sporadic, but the negative table values and the histograms show that lead was released from the soils in many of the extractions (Figures 174 to 177 and 225 to 228, and Tables 92 to 94 and 119 to 121). The concentration of lead in the soil effluents typically were moderate in the first five and low in the last two extractions.

Nickel

Very low concentrations of nickel (ranging from 0.06 to 1.4 μg/ml) were present in most of the waste extracts (Tables 75 and 76, and Figures 178 and 229). Totals of 4.0 and 3.2 μg/g were extracted by methods A and B, respectively, which is over 100 percent of that found by the repeated aqua regia digestion of the waste. Figures 179 to 182 and 230 to 233, and Tables 95 to 97 and 122 to 124 show that considerable amounts of nickel were displaced from the soils by these extracts: 5 to 21 times as much as was in the extracts produced by method A and 4 to 11 times as much as in the method B extracts. The concentration of nickel in the soil extracts ranged from 1.2 to 21.5 μg/ml by method A and 0.4 to 2.5 μg/ml by method B before the detection limit was reached.

Titanium

Very, very low concentrations of titanium (0.91 to 0.12 μg/ml) leached out of the soil re-refining waste (Tables 75 and 76, and Figures 183 and 234). Totals of 3.6 and 2.7 μg/g were extracted by methods A and B, respectively; this is about 100 and 90 percent of the titanium content of the waste. These acidic leachates removed a lot of titanium from the soil — up to 80 times more than was present in the leachate (Figures 184 to 187 and 235 to 238, and Tables 98 to 100 and 125 to 127).

Zinc

Moderate concentrations of zinc were found in the initial extractions (913 and 155 μg/ml) but they dropped to very low concentrations by the fifth extraction. Totals of 2740 and 2204 μg/g were extracted by the two methods; this is over 100 percent of that found by the repeated aqua regia digestion of the tarry waste (Tables 75 and 76 and Figures 188 and 239). Although zinc was retained by the soil in the first extraction, it generally was being

released again throughout the remainder of the series of extractions (Figures 189 to 192 and 240 to 243, and Tables 101 to 103 and 128 to 130).

Summary

The water extracts of this highly acidic organic waste contained very low to moderate concentrations of the metals of interest. In every case, the later waste extracts caused the release of these elements from the soils.

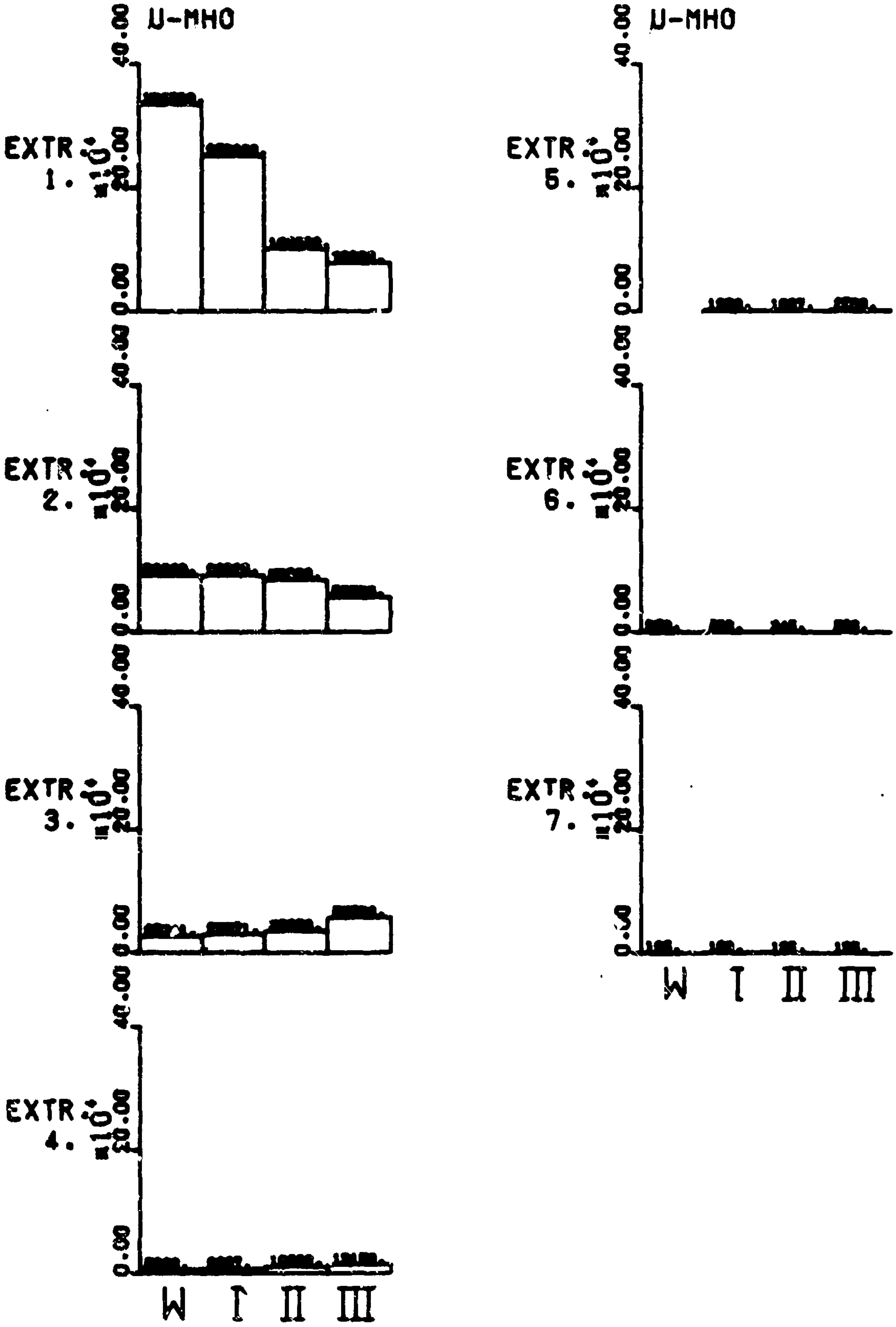


FIGURE 142. CONDUCTANCE OF EXTRACT FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

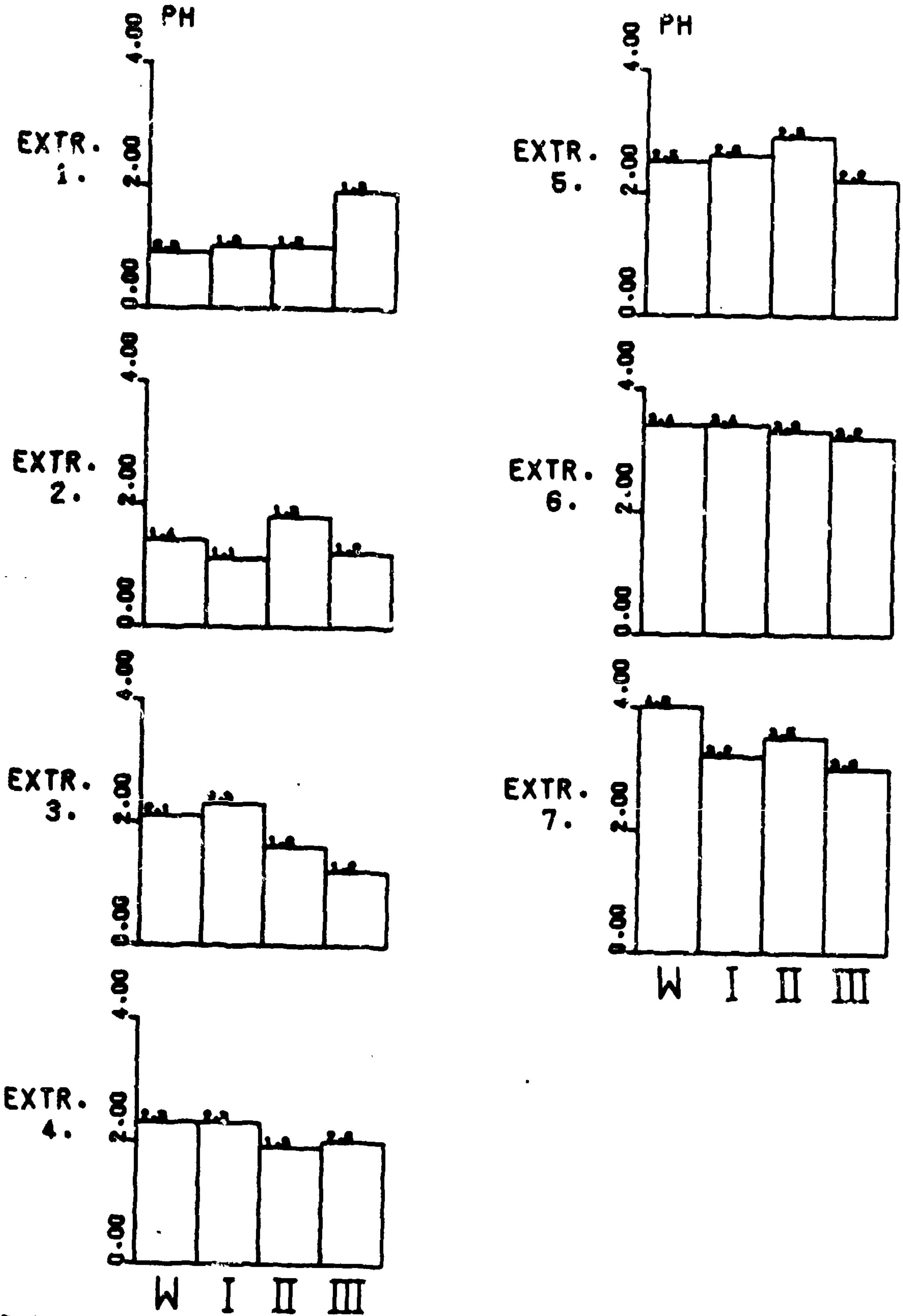


FIGURE 143. pH OF EXTRACT FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

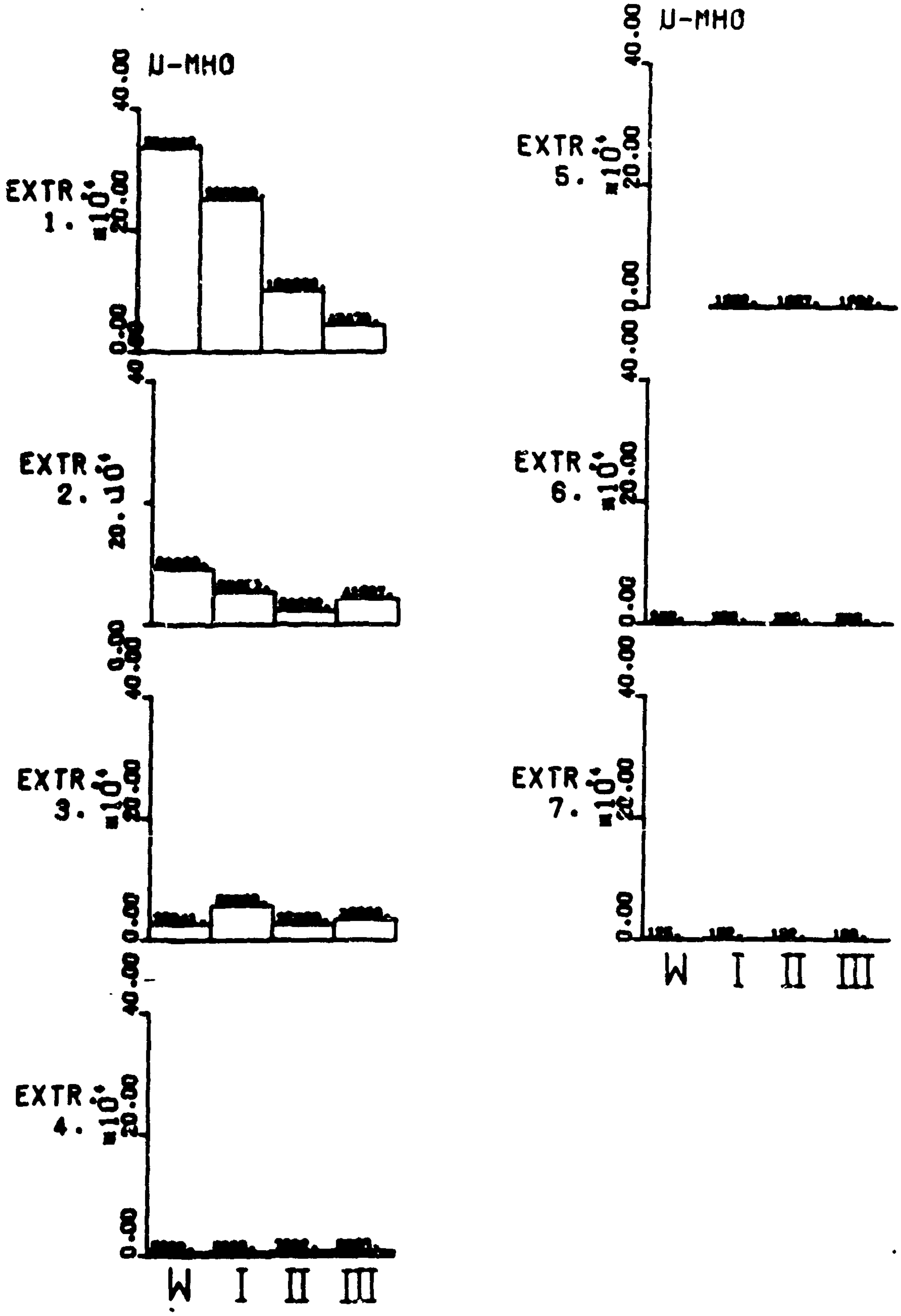


FIGURE 144. CONDUCTANCE OF EXTRACT FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

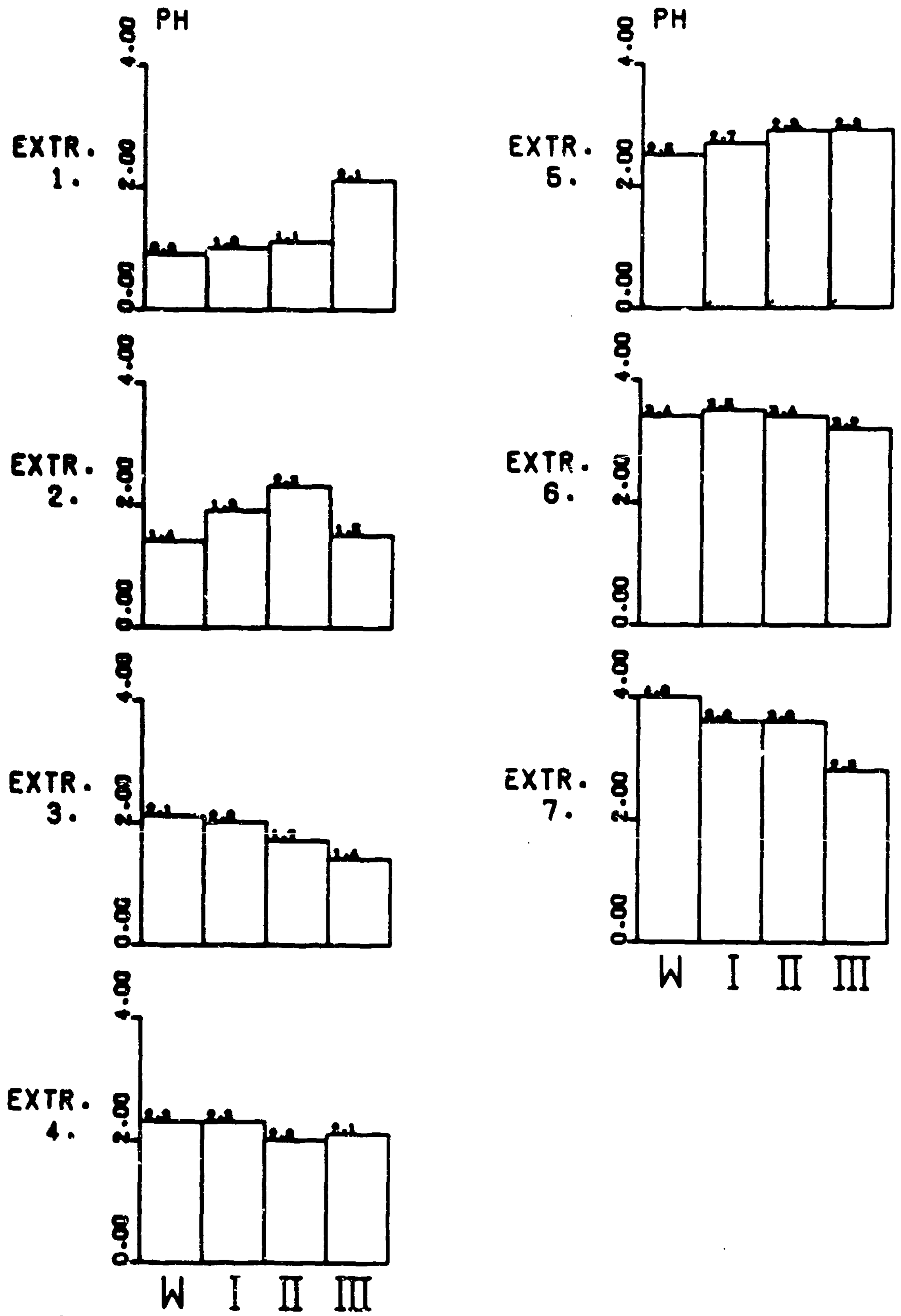


FIGURE 145. pH OF EXTRACT FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

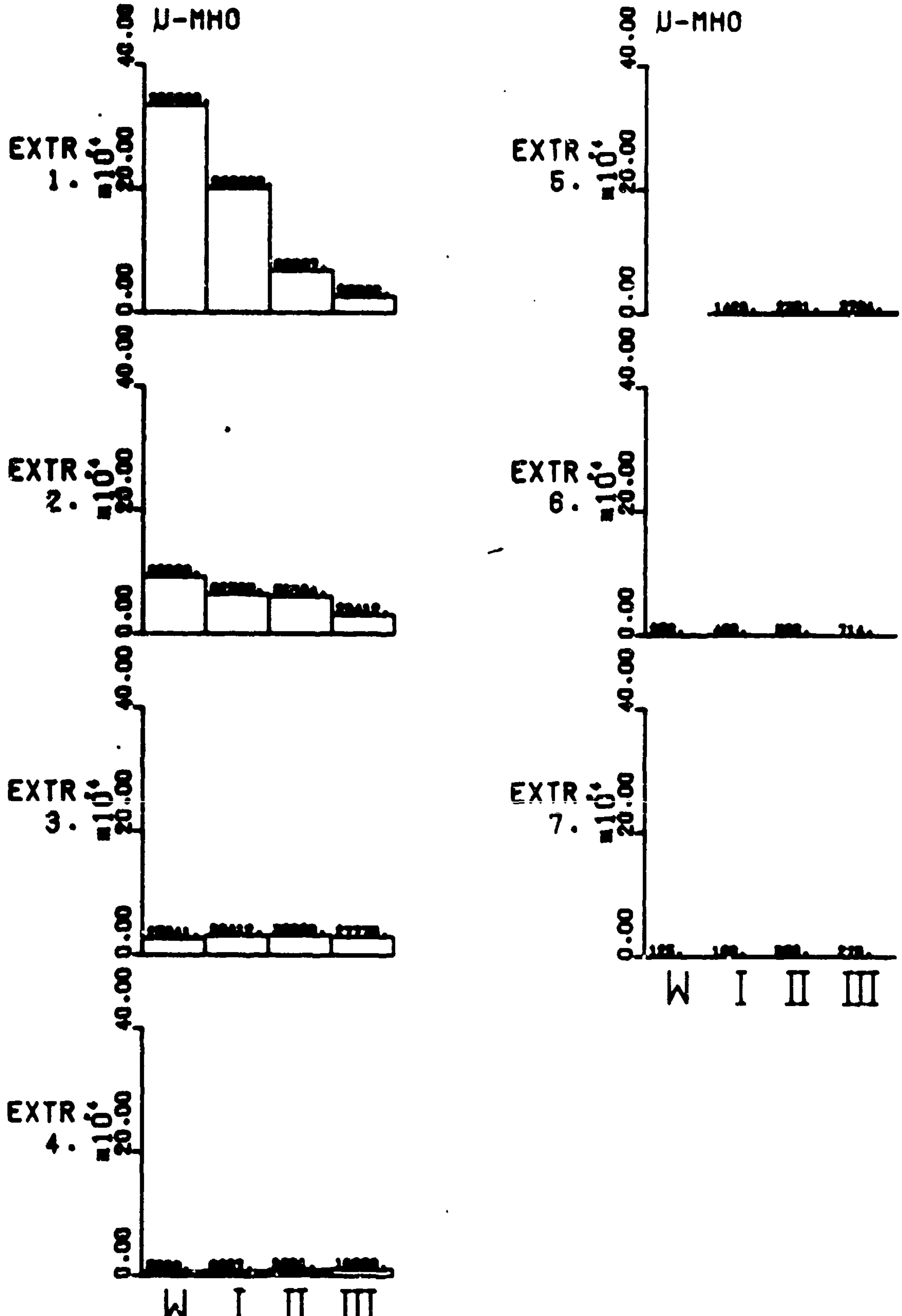


FIGURE 146. CONDUCTANCE OF EXTRACT FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

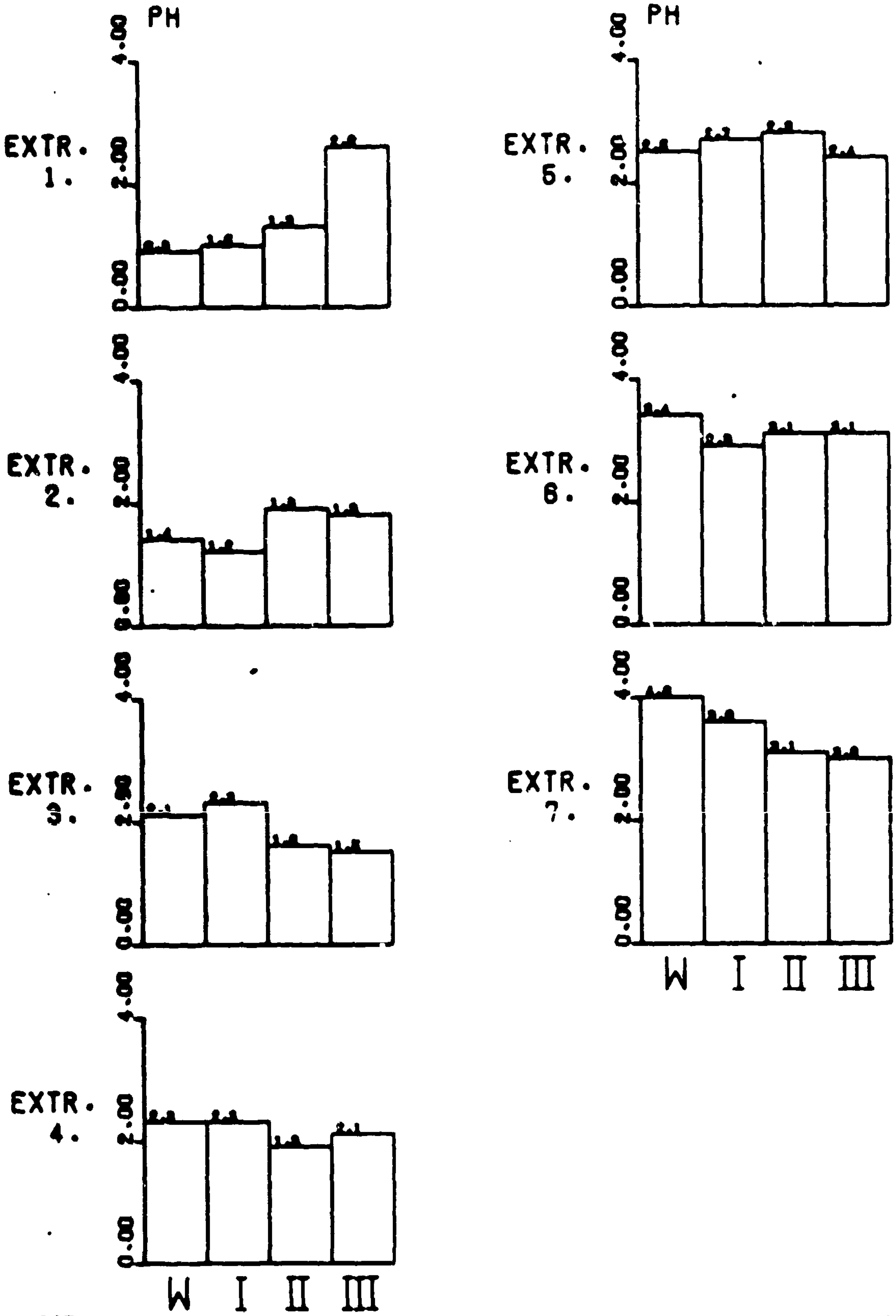


FIGURE 147. pH OF EXTRACT FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

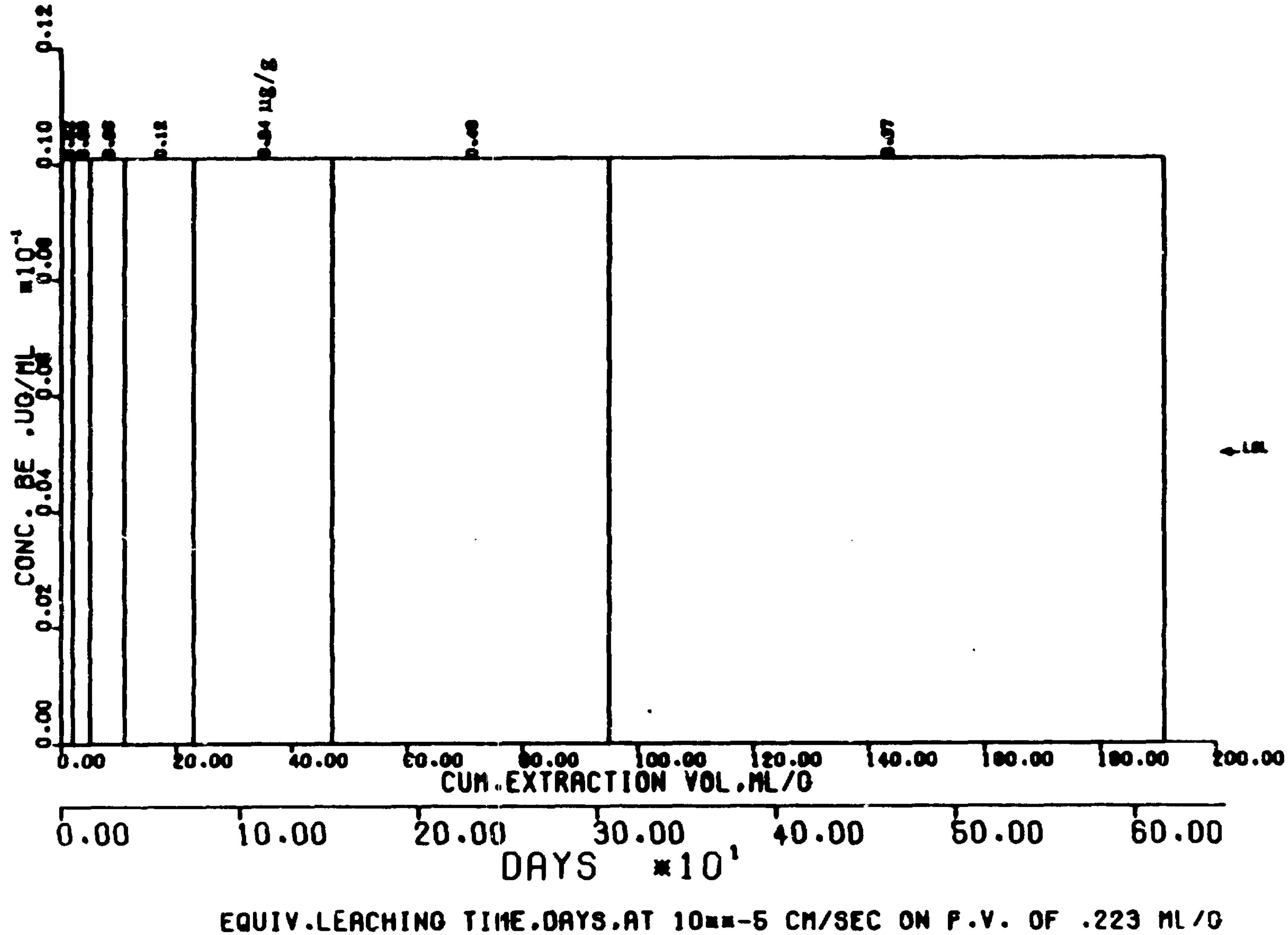


FIGURE 148. EXTRACTION OF BERYLLIUM FROM OIL RE-REFINING WASTE (A).

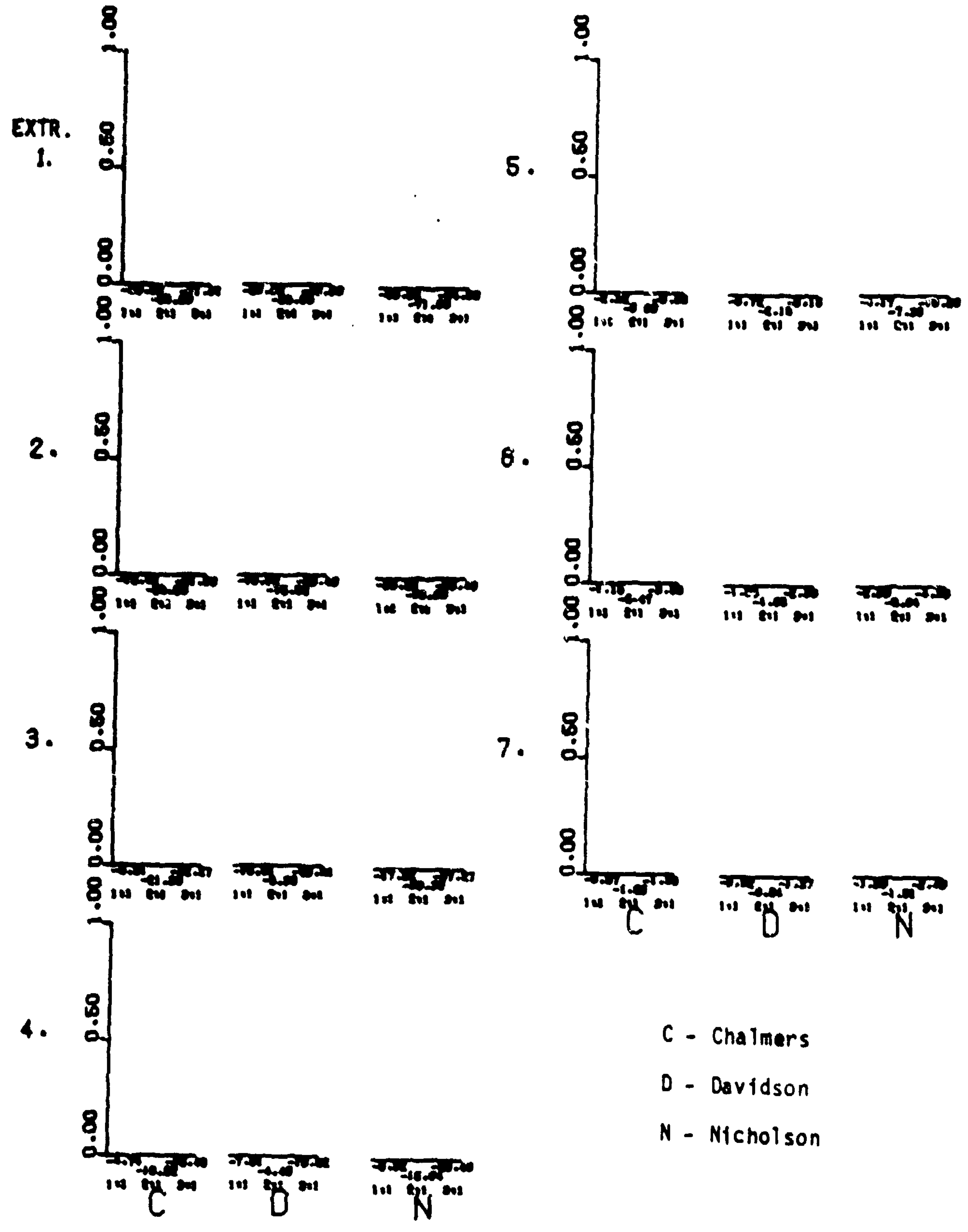


FIGURE 149. COMPARING FRACTION BERYLLIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 77. BERYLLIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.01	.02										
	I	.36	.73	-.71	.02	-.71	-35.00	-35.00	36.00	2.19	65.46	-.97	-44.19
	II	.58	1.15	-.42	.73	-.42	-.58	-.58	1.58	1.63	58.46	-.37	-20.22
	III	.73	1.45	-.30	1.15	-.30	-.26	-.26	1.26	1.37	53.93	-.21	-11.77
	I+II			-.57	.01	-.57	-56.00	-56.00	57.00	7.01	81.88	-.98	-44.49
	I+II+III			-.40	.01	-.40	-71.00	-71.00	72.00	13.25	85.68	-.99	-44.60
2	W	.01	.03										
	I	.10	.30	-.27	.05	-.98	-9.00	-19.40	10.00	4.36	77.07	-3.23	-72.81
	II	.30	.91	-.61	1.03	-1.03	-2.00	-1.00	3.00	1.40	54.40	-1.13	-48.58
	III	.40	1.21	-.30	2.06	-.61	-.33	-.29	1.33	1.40	54.42	-.50	-26.57
	I+II			-.44	.03	-1.00	-29.00	-39.80	30.00	7.91	82.79	-2.21	-65.66
	I+II+III			-.39	.02	-.87	-39.00	-51.80	40.00	14.92	86.17	-2.16	-65.14
3	W	.01	.06										
	I	.03	.18	-.12	.11	-1.10	-2.00	-9.91	3.00	6.60	81.38	-6.06	-80.62
	II	.07	.42	-.24	1.21	-1.27	-1.33	-1.05	2.33	2.42	67.56	-3.00	-71.57
	III	.17	1.03	-.61	2.40	-1.21	-1.43	-.49	2.43	1.06	46.56	-1.10	-49.64
	I+II			-.18	.06	-1.19	-6.00	-21.36	7.00	16.09	86.44	-5.60	-79.87
	I+II+III			-.32	.04	-1.20	-16.00	-32.27	17.00	16.61	86.56	-3.40	-73.97
4	W	.01	.12										
	I	.01	.12	.00	.23	-1.10	.00	-4.74	1.00	9.89	84.23	-9.08	-83.72
	II	.01	.12	.00	1.33	-1.27	.00	-.95	1.00	8.40	83.27	-10.50	-84.56
	III	.03	.36	-.24	2.61	-1.45	-2.00	-.56	3.00	2.33	66.73	-4.00	-75.96
	I+II			.00	.12	-1.19	.00	-10.22	1.00	56.32	88.98	-19.50	-87.08
	I+II+III			-.00	.08	-1.28	-2.00	-16.40	3.00	46.40	88.77	-10.53	-84.57
5	W	.01	.24										
	I	.01	.24	.00	.47	-1.10	.00	-2.32	1.00	4.95	78.57	-4.54	-77.58
	II	.01	.24	.00	1.58	-1.27	.00	-.81	1.00	4.24	76.72	-5.25	-79.22
	III	.01	.24	.00	2.05	-1.45	.00	-.51	1.00	3.49	74.00	-6.00	-80.54
	I+II			.00	.24	-1.19	.00	-5.00	1.00	28.16	87.97	-9.79	-84.17
	I+II+III			.00	.16	-1.28	.00	-8.06	1.00	69.60	89.18	-15.79	-86.38
6	W	.01	.40										
	I	.01	.40	.00	.96	-1.10	.00	-1.15	1.00	2.47	67.99	-2.27	-66.23
	II	.01	.40	.00	2.06	-1.27	.00	-.62	1.00	2.12	64.74	-2.63	-69.15
	III	.01	.40	.00	3.33	-1.45	.00	-.44	1.00	1.74	60.17	-3.00	-71.57
	I+II			.00	.40	-1.19	.00	-2.47	1.00	14.08	85.94	-4.90	-78.46
	I+II+III			.00	.32	-1.28	.00	-3.99	1.00	34.80	88.35	-7.90	-82.78
7	W	.01	.97										
	I	.01	.97	.00	1.93	-1.10	.00	-.57	1.00	1.24	51.04	-1.14	-48.63
	II	.01	.97	.00	3.03	-1.27	.00	-.42	1.00	1.06	46.66	-1.31	-52.70
	III	.01	.97	.00	4.30	-1.45	.00	-.34	1.00	.87	41.09	-1.50	-56.31
	I+II			.00	.96	-1.19	.00	-1.23	1.00	7.04	81.92	-2.45	-67.70
	I+II+III			.00	.64	-1.28	.00	-1.98	1.00	17.40	86.71	-3.95	-75.79

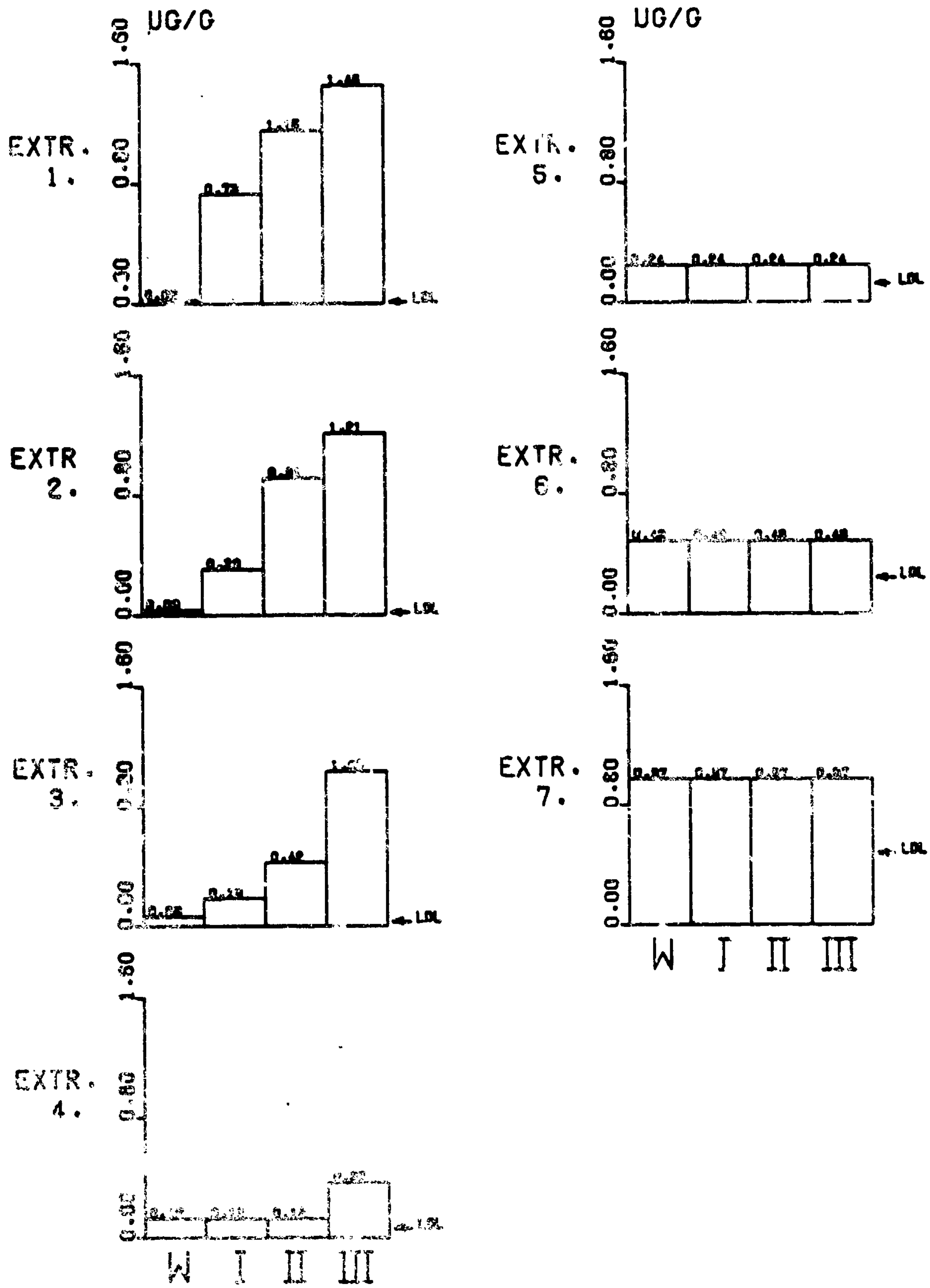


FIGURE 150. WEIGHT OF BERYLLIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 78. BERYLLIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.01	.02										
	I	.27	.55	-.53	.02	-.53	-26.00	-26.00	27.00	4.63	77.81	-.96	-43.92
	II	.39	.79	-.24	.55	-.24	-.44	-.44	1.44	3.56	74.33	-.31	-17.10
	III	.41	.83	-.04	.79	-.04	-.05	-.05	1.05	3.63	74.61	-.05	-2.79
	I+II			-.38	.01	-.38	-38.00	-38.00	39.00	14.51	86.06	-.97	-44.26
	I+II+III			-.27	.01	-.27	-40.00	-40.00	41.00	32.17	88.22	-.70	-44.29
2	W	.01	.03										
	I	.18	.38	-.27	.05	-.80	-9.00	-15.00	10.00	7.43	82.34	-2.63	-69.21
	II	.02	.04	.24	.05	-.00	.80	-.00	.20	50.33	88.86	-.00	-.00
	III	.25	.76	-.70	.05	-.74	-11.50	-.87	12.50	3.05	71.86	-.97	-44.23
	I+II			-.02	.03	-.40	-1.00	-15.00	2.00	100.15	89.70	-13.17	-85.66
	I+II+III			-.24	.02	-.51	-24.00	-30.40	25.00	34.21	88.33	-2.03	-63.74
3	W	.01	.06										
	I	.17	1.03	-.97	.11	-1.77	-16.00	-15.91	17.00	1.24	51.23	-1.72	-59.76
	II	.05	.39	.73	1.06	.73	.71	.39	.29	12.47	85.41	2.40	67.38
	III	.14	.85	-.55	1.15	-1.28	-1.00	-1.11	2.00	2.08	64.36	-1.51	-56.52
	I+II			-.12	.06	-.52	-4.00	-9.36	5.00	36.93	88.44	-3.43	-73.76
	I+II+III			-.26	.04	-.77	-13.00	-20.91	14.00	29.62	88.07	-2.74	-69.94
4	W	.01	.12										
	I	.01	.12	.00	.23	-1.77	.00	-7.61	1.00	10.58	84.60	-14.58	-86.08
	II	.01	.12	.00	2.00	.73	.00	.36	1.00	31.17	88.16	6.08	80.54
	III	.02	.24	-.12	1.27	-1.40	-1.00	-1.10	2.00	6.79	81.62	-5.79	-80.20
	I+II			.00	.12	-.52	.00	-4.48	1.00	92.08	89.38	-8.58	-83.35
	I+II+III			-.04	.08	-.81	-1.00	-10.52	2.00	103.16	89.44	-10.00	-84.34
5	W	.01	.24										
	I	.01	.24	.00	.47	-1.77	.00	-3.72	1.00	5.29	79.30	-7.29	-82.19
	II	.01	.24	.00	2.24	.73	.00	.32	1.00	15.58	86.33	3.00	71.57
	III	.01	.24	.00	1.52	-1.40	.00	-.93	1.00	6.79	81.62	-5.79	-80.20
	I+II			.00	.24	-.52	.00	-2.19	1.00	46.04	88.76	-4.29	-76.88
	I+II+III			.00	.16	-.81	.00	-5.15	1.00	103.16	89.44	-10.00	-84.34
6	W	.01	.48										
	I	.01	.48	.00	.96	-1.77	.00	-1.84	1.00	2.65	69.29	-3.65	-74.66
	II	.01	.48	.00	2.73	.73	.00	.27	1.00	7.79	82.69	1.50	56.31
	III	.01	.48	.00	2.00	-1.40	.00	-.70	1.00	3.40	73.59	-2.90	-70.95
	I+II			.00	.48	-.52	.00	-1.08	1.00	23.02	87.51	-2.15	-65.01
	I+II+III			.00	.32	-.81	.00	-2.55	1.00	51.58	88.89	-5.04	-78.78
7	W	.02	.97										
	I	.01	.97	.00	1.93	-1.77	.00	-.92	1.00	1.32	52.91	-1.82	-61.25
	II	.01	.97	.00	3.70	.73	.00	.20	1.00	3.90	75.60	.75	36.87
	III	.01	.97	.00	2.97	-1.40	.00	-.47	1.00	1.70	59.50	-1.45	-55.37
	I+II			.00	.96	-.52	.00	-.54	1.00	11.51	85.03	-1.07	-47.01
	I+II+III			.00	.64	-.81	.00	-1.27	1.00	25.79	87.78	-2.52	-68.36

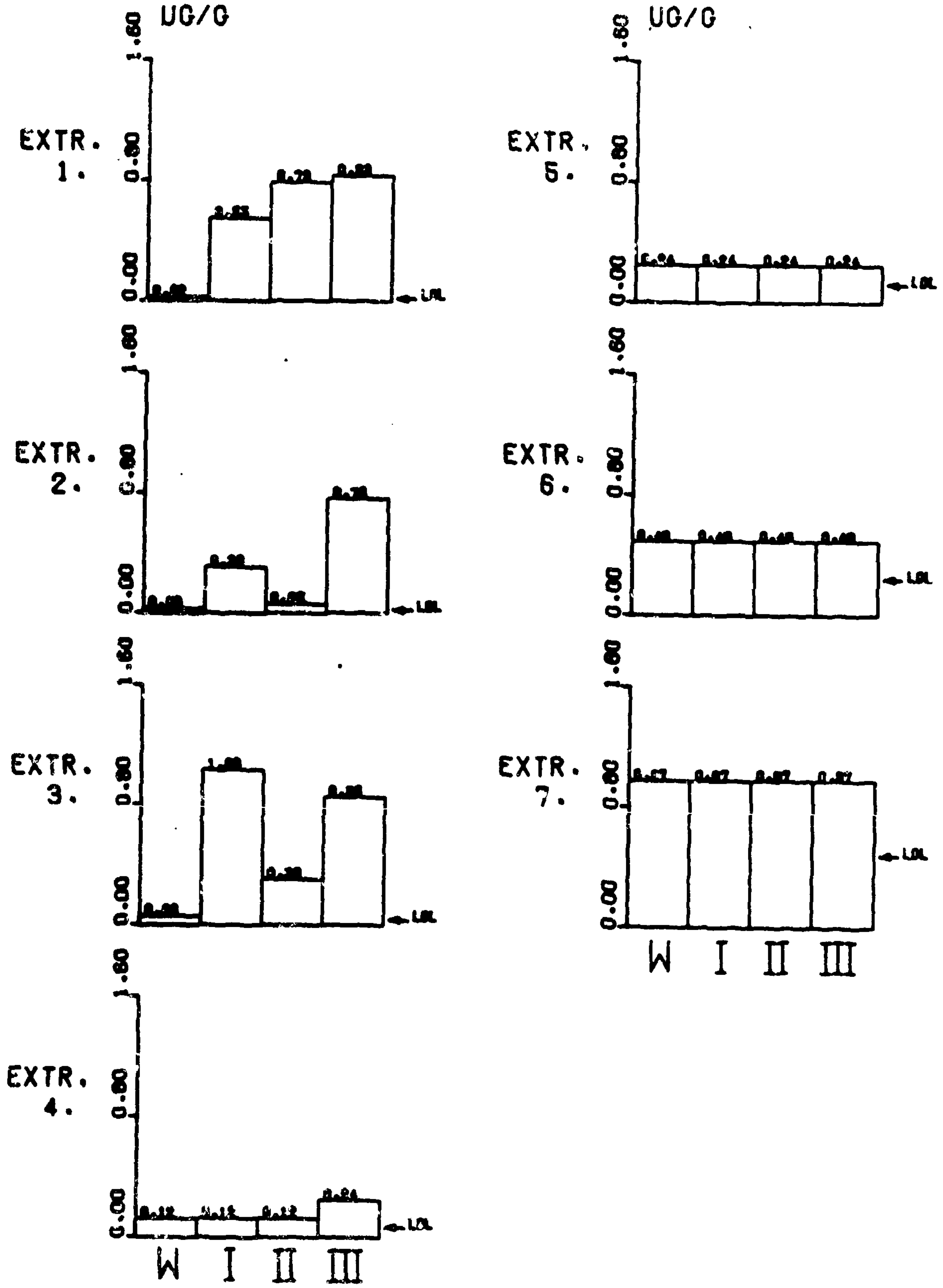


FIGURE 151 WEIGHT OF BERYLLIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

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TABLE 79. BERYLLIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.01	.02										
	I	.55	1.09	-1.07	.02	-1.07	-53.00	-53.00	54.00	2.00	63.41	-.98	-44.46
	II	.73	1.45	-.36	1.09	-.36	-.33	-.33	1.33	1.98	63.26	-.25	-14.04
	III	.66	1.31	.14	1.45	.14	.10	.10	.90	2.48	68.04	.11	6.15
	I+II			-.72	.01	-.72	-71.00	-71.00	72.00	7.95	82.83	-.99	-44.60
	I+II+III			-.43	.01	-.43	-64.00	-44.00	65.00	21.29	87.31	-.98	-44.56
2	W	.01	.03										
	I	.21	.64	-.61	.05	-1.68	-20.00	-33.20	21.00	2.47	67.98	-2.63	-69.22
	II	.47	1.42	-.79	1.73	-1.15	-1.24	-.67	2.24	1.47	55.84	-.81	-38.96
	III	.60	1.79	-.36	2.08	-.22	-.26	-.08	1.26	1.69	59.44	-.12	-7.09
	I+II			-.70	.03	-1.41	-46.00	-56.00	47.00	7.14	82.03	-1.99	-63.27
	I+II+III			-.59	.02	-1.02	-58.00	-60.40	59.00	14.66	86.10	-1.71	-59.63
3	W	.01	.06										
	I	.06	.36	-.30	.11	-1.98	-5.00	-17.82	6.00	3.49	74.03	-5.44	-79.59
	II	.10	.61	-.24	2.09	-1.39	-.67	-.67	1.67	3.06	71.92	-2.30	-66.50
	III	.19	1.15	-.55	3.40	-.77	-.90	-.22	1.90	2.16	65.12	-.67	-33.69
	I+II			-.27	.06	-1.69	-9.00	-39.36	10.00	15.89	86.40	-5.57	-79.82
	I+II+III			-.36	.04	-1.38	-18.00	-37.27	19.00	21.81	87.37	-3.60	-74.46
4	W	.01	.12										
	I	.01	.12	.00	.23	-1.98	.00	-8.52	1.00	10.40	84.55	-16.33	-86.50
	II	.02	.24	-.12	2.21	-1.52	-1.00	-.68	2.00	7.16	82.05	-6.25	-80.91
	III	.06	.73	-.40	3.73	-1.25	-2.00	-.34	3.00	2.75	70.00	-1.72	-59.84
	I+II			-.06	.12	-1.75	-1.00	-15.04	2.00	39.21	88.54	-14.42	-86.03
	I+II+III			-.20	.08	-1.58	-5.00	-20.43	6.00	33.69	88.30	-6.53	-81.29
5	W	.01	.24										
	I	.01	.24	.00	.47	-1.98	.00	-4.17	1.00	5.24	79.20	-8.17	-83.02
	II	.01	.24	.00	2.45	-1.52	.00	-.62	1.00	7.16	82.05	-6.25	-80.91
	III	.01	.24	.00	3.97	-1.25	.00	-.32	1.00	8.24	83.08	-5.17	-79.05
	I+II			.00	.24	-1.75	.00	-7.36	1.00	39.21	88.54	-14.42	-86.03
	I+II+III			.00	.16	-1.58	.00	-10.00	1.00	101.08	89.43	-19.58	-87.08
6	W	.01	.48										
	I	.01	.48	.00	.96	-1.98	.00	-2.06	1.00	2.62	69.11	-4.08	-76.24
	II	.01	.48	.00	2.94	-1.52	.00	-.52	1.00	3.58	74.39	-3.13	-72.26
	III	.02	.48	.00	4.45	-1.25	.00	-.28	1.00	4.12	76.36	-2.58	-68.84
	I+II			.00	.48	-1.75	.00	-3.64	1.00	19.61	87.08	-7.21	-82.10
	I+II+III			.00	.32	-1.58	.00	-4.95	1.00	50.54	88.87	-9.79	-84.17
7	W	.01	.97										
	I	.01	.97	.00	1.93	-1.98	.00	-1.03	1.00	1.31	52.65	-2.04	-63.90
	II	.01	.97	.00	3.91	-1.52	.00	-.39	1.00	1.79	60.80	-1.56	-57.38
	III	.01	.97	.00	5.42	-1.25	.00	-.23	1.00	2.06	64.11	-1.29	-52.25
	I+II			.00	.96	-1.75	.00	-1.81	1.00	9.80	84.18	-3.60	-74.49
	I+II+III			.00	.64	-1.58	.00	-2.46	1.00	25.27	87.73	-4.90	-78.46

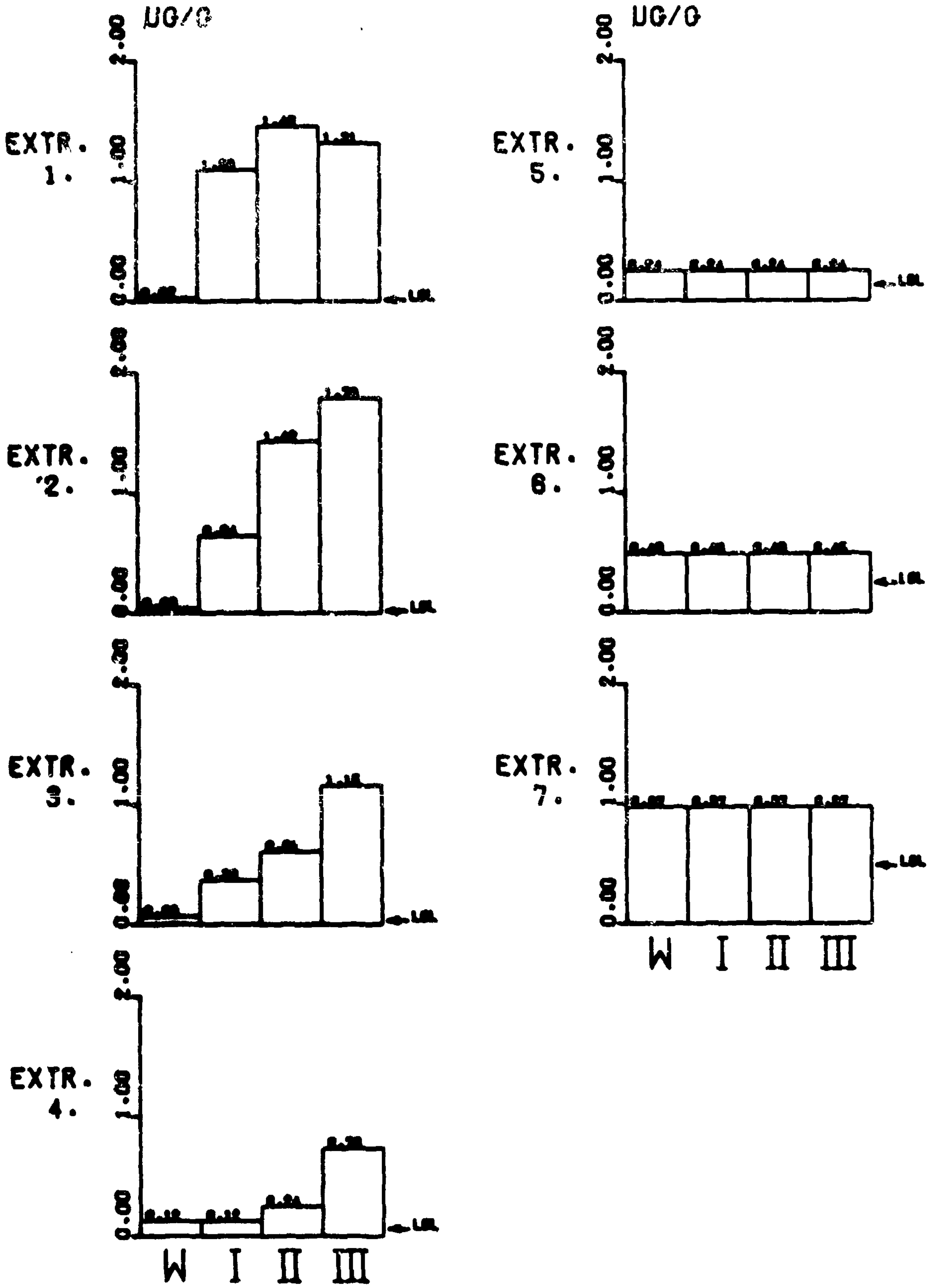

FIGURE 152. WEIGHT OF BERYLLIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

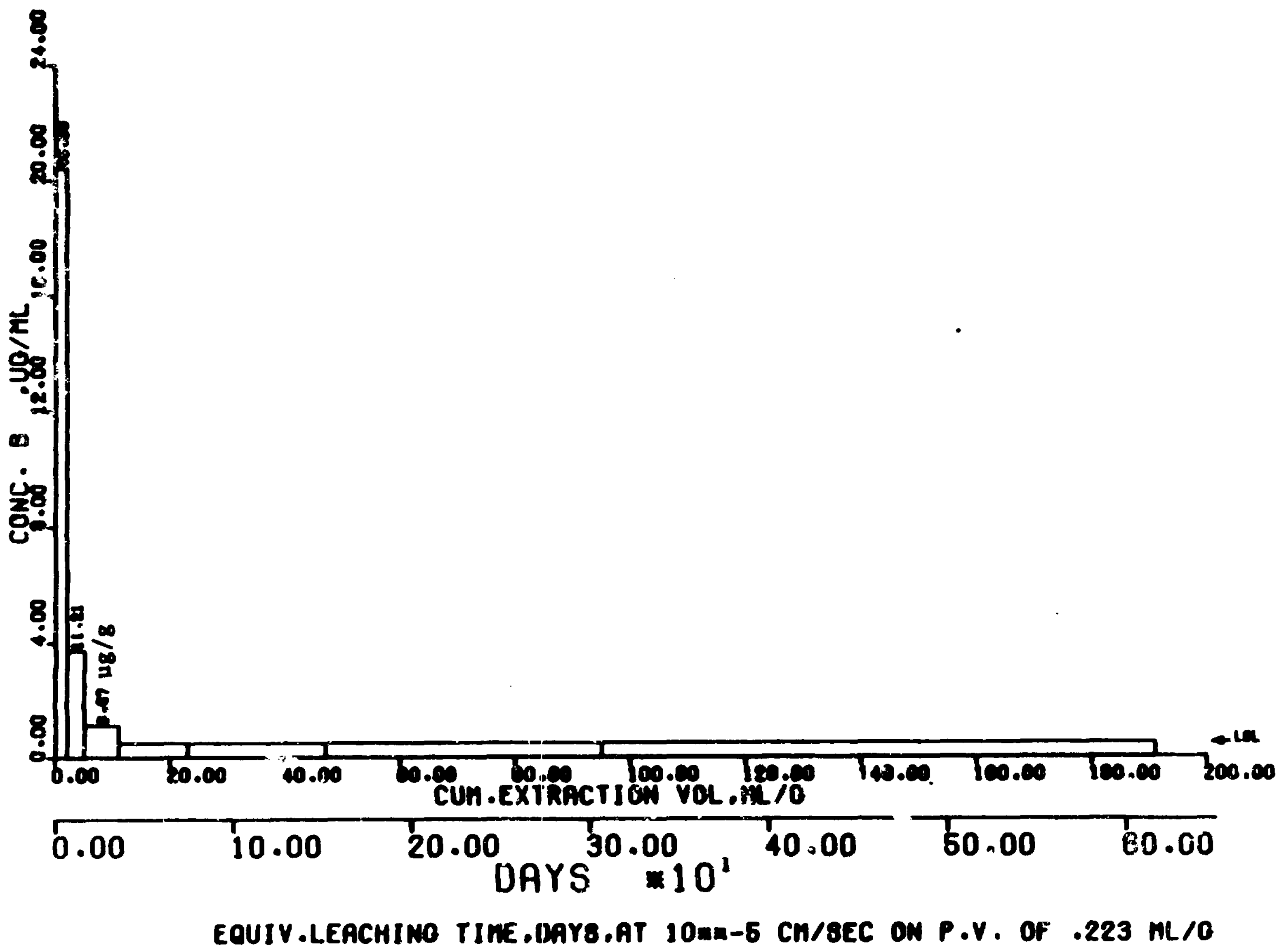

FIGURE 153. EXTRACTION OF BORON FROM OIL RE-REFINING WASTE (A).

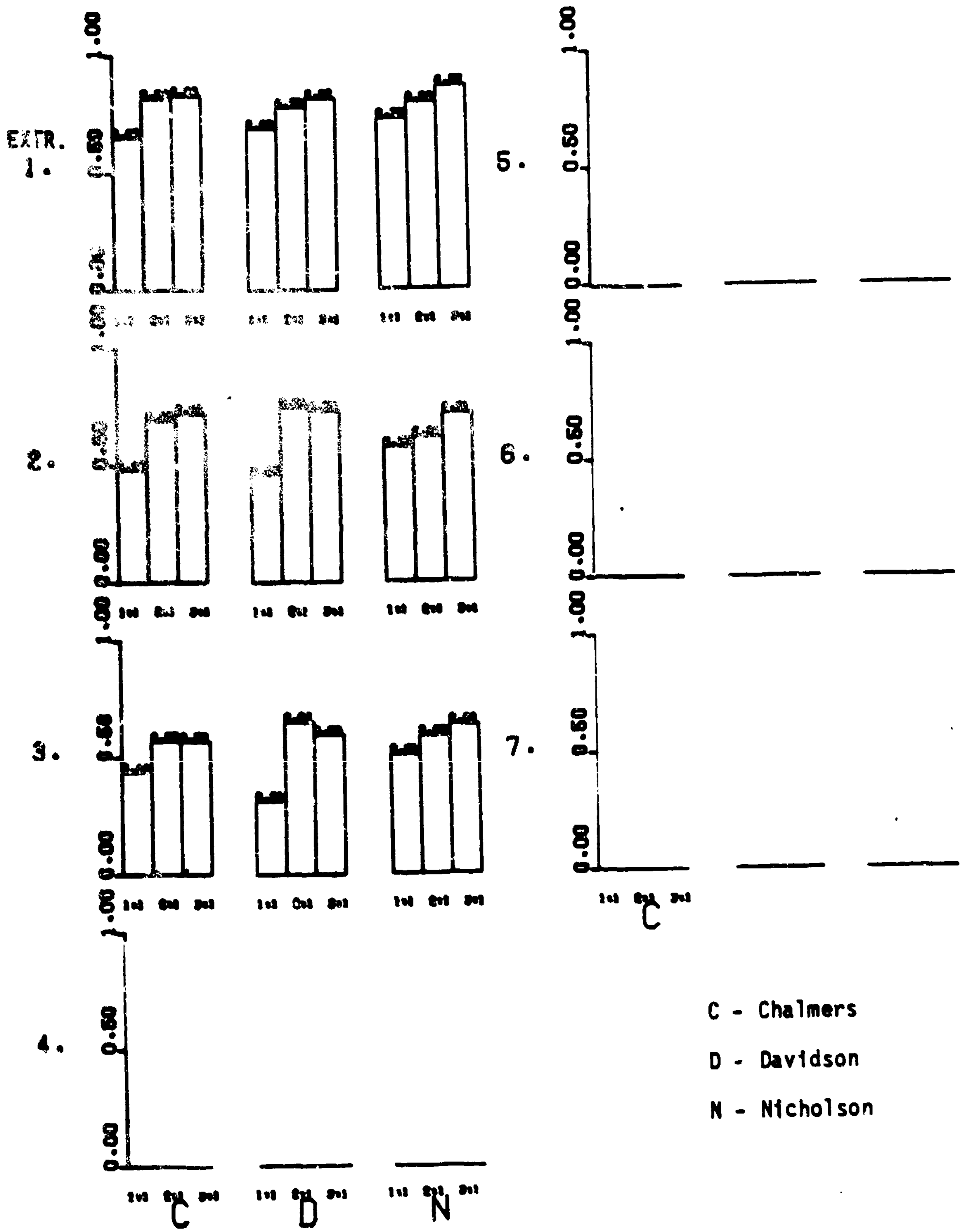

FIGURE 154. COMPARING FRACTION BORON RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 80. BORON FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	[illegible] RETD. THIS EXTR.	[illegible] RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	U	20.40	40.80										
	I	7.17	14.34	26.46	40.80	26.46	.65	.65	.35	3.07	71.93	1.85	61.54
	II	3.74	7.47	6.87	14.34	6.87	.48	.48	.52	3.26	72.95	.92	42.50
	III	3.53	7.07	.40	7.47	.40	.05	.05	.95	2.53	68.45	.06	3.27
	I+II			16.67	20.40	16.67	.82	.82	.18	13.83	85.86	4.46	77.36
	I+II+III			11.24	13.60	11.24	.83	.83	.17	27.85	87.88	4.77	78.16
2	U	3.74	11.22										
	I	4.24	12.73	-1.51	52.91	24.95	-.14	.46	1.14	3.34	73.31	1.96	62.97
	II	2.93	8.79	3.94	27.07	10.91	.31	.40	.69	3.22	72.75	1.23	50.89
	III	2.53	7.58	1.21	16.26	1.62	.14	.10	.86	2.52	68.38	.21	12.04
	I+II			1.21	26.01	17.88	.22	.69	.78	12.04	85.25	4.07	76.19
	I+II+III			1.21	17.34	12.46	.32	.72	.68	25.73	87.77	4.93	78.54
3	U	1.11	6.67										
	I	1.91	6.06	.64	50.60	25.55	.99	.44	.91	7.10	81.99	4.22	76.66
	II	1.52	9.09	-3.03	33.13	7.78	-.50	.23	1.50	2.78	70.22	.86	40.55
	III	1.82	10.91	-1.82	25.35	-.20	-.20	-.01	1.20	1.59	57.76	-.02	-1.06
	I+II			-1.21	29.34	16.67	-.36	.57	1.36	11.37	84.97	3.67	74.74
	I+II+III			-1.41	19.56	11.04	-.64	.56	1.64	17.40	86.73	3.04	71.77
4	U	<.50	<6.06										
	I	<.50	<6.06										
	II	<.50	<6.06										
	III	<.50	<6.06										
	I+II												
	I+II+III												
5	U	<.50	<12.12										
	I	<.50	<12.12										
	II	<.50	<12.12										
	III	<.50	<12.12										
	I+II												
	I+II+III												
6	U	<.50	<24.24										
	I	<.50	<24.24										
	II	<.50	<24.24										
	III	<.50	<24.24										
	I+II												
	I+II+III												
7	U	<.50	<48.48										
	I	<.50	<48.48										
	II	<.50	<48.48										
	III	<.50	<48.48										
	I+II												
	I+II+III												

The remainder of the table was not calculated because the concentrations were below the detection limit.

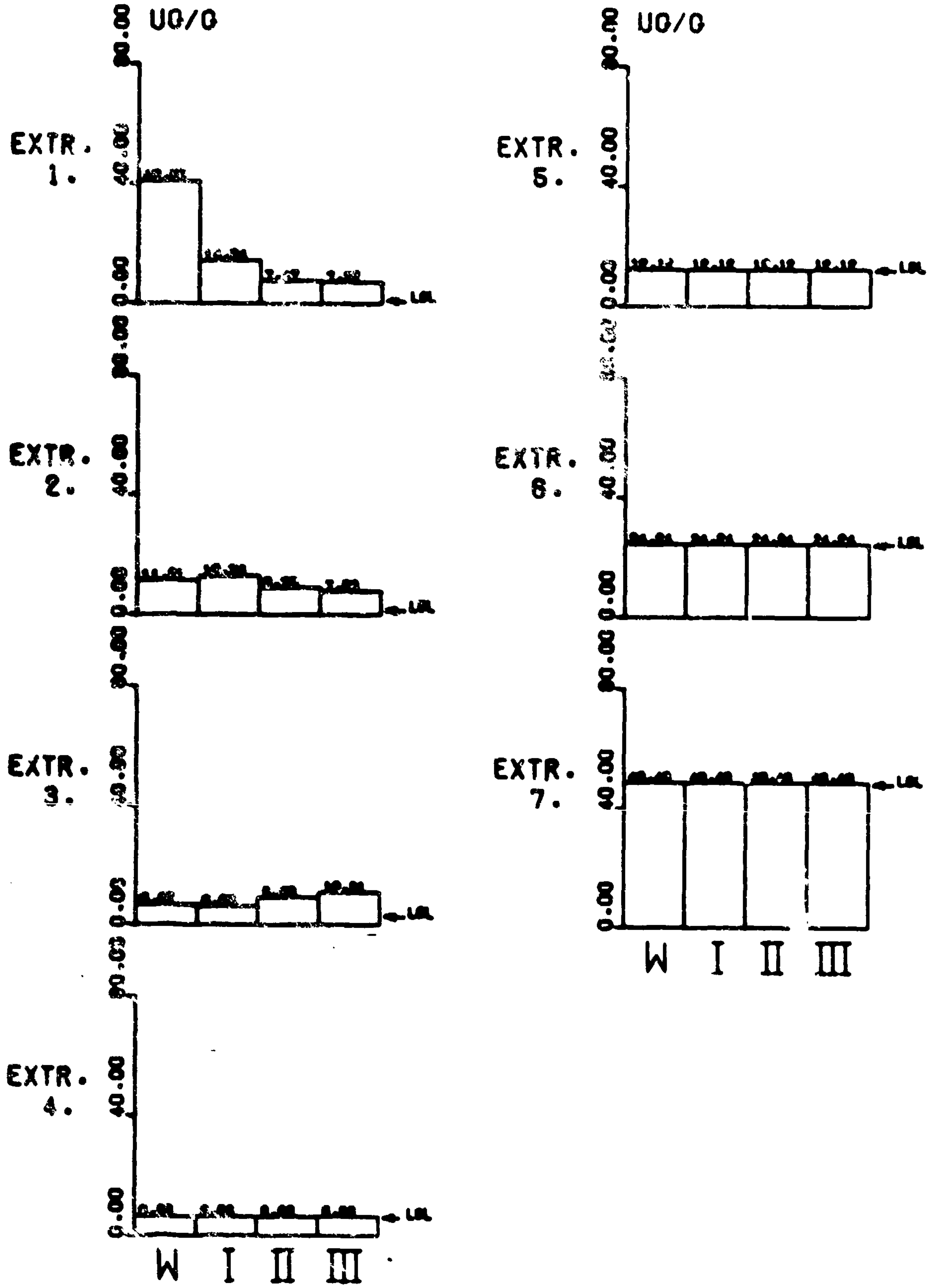

FIGURE 155. WEIGHT OF BORON FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 81. BORON FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	20.40	40.80										
	I	6.36	12.73	28.08	40.80	28.08	.69	.69	.31	4.49	77.19	2.21	65.62
	II	4.55	9.09	3.64	12.73	3.64	.29	.29	.71	3.47	73.92	.49	21.00
	III	3.74	7.47	1.62	9.09	1.62	.18	.18	.82	3.95	75.79	.22	12.20
	I+II			15.86	20.40	15.86	.78	.78	.22	15.77	86.37	3.49	74.01
	I+II+III			11.11	13.60	11.11	.82	.82	.18	30.06	88.09	4.46	77.36
2	W	3.74	11.21										
	I	5.15	15.45	-4.24	52.01	23.84	-.38	.46	1.38	3.35	73.37	1.54	57.04
	II	1.41	4.24	11.21	30.18	[illegible].85	.73	.53	.27	10.08	84.33	3.50	74.05
	III	2.22	6.67	-2.42	13.33	-.01	-.57	-.06	1.57	4.06	76.18	-.12	-6.91
	I+II			3.40	26.01	19.34	.62	.74	.38	35.43	88.38	9.12	83.74
	I+II+III			1.52	17.34	12.63	.41	.73	.59	43.35	88.68	5.68	80.02
3	W	1.11	6.67										
	I	2.06	12.12	-5.45	58.68	18.38	-.02	.31	1.02	3.82	75.33	1.52	56.66
	II	1.21	7.27	4.85	48.36	19.69	.40	.49	.60	6.54	81.31	2.71	69.73
	III	1.62	9.70	-2.42	28.69	-3.23	-.33	-.16	1.33	2.54	68.54	-.33	-18.43
	I+II			-.38	29.34	19.84	-.09	.65	1.99	20.50	87.22	5.24	79.19
	I+II+III			-1.01	19.56	11.62	-.45	.59	1.45	29.49	88.06	3.59	74.45
4	W	<.50	<6.06										
	I	<.50	<6.06										
	II	.60	7.15										
	III	<.50	<6.06										
	I+II												
	I+II+III												
5	W	<.50	<12.12										
	I	<.50	<12.12										
	II	<.50	<12.12										
	III	<.50	<12.12										
	I+II												
	I+II+III												
6	W	<.50	<24.24										
	I	<.50	<24.24										
	II	<.50	<24.24										
	III	<.50	<24.24										
	I+II												
	I+II+III												
7	W	<.50	<48.48										
	I	<.50	<48.48										
	II	<.50	<48.48										
	III	<.50	<48.48										
	I+II												
	I+II+III												

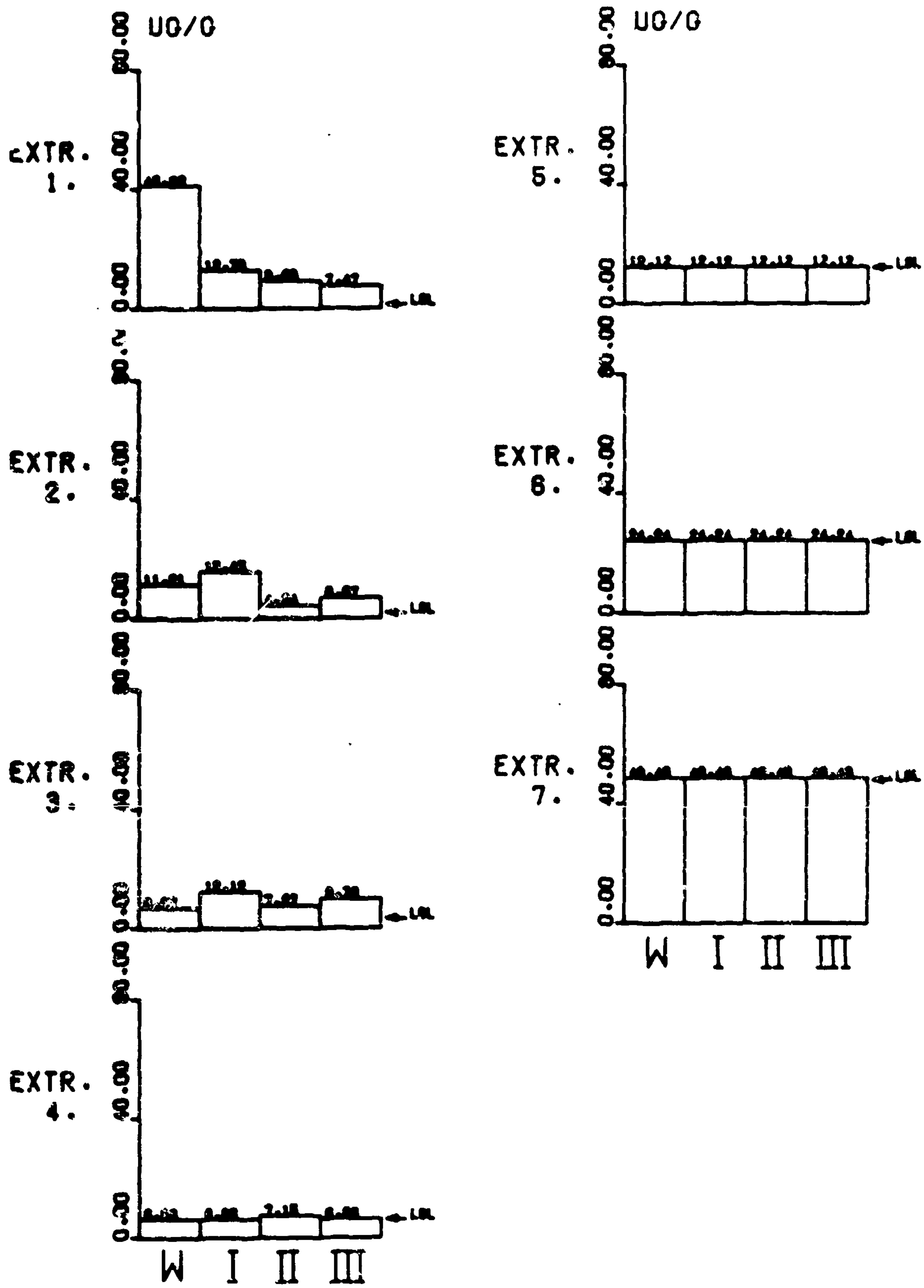

FIGURE 156. WEIGHT OF BORON FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 82. BORON FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	U	20.40	40.00										
	I	5.56	11.11	29.69	40.00	29.69	.73	.73	.27	4.37	77.12	2.67	69.49
	II	4.14	8.28	[illegible]	11.11	2.83	.25	.25	.75	2.62	69.13	.34	18.85
	III	2.73	5.45	2.83	8.28	2.83	.34	.34	.66	3.90	75.91	.52	27.41
	I+II			16.26	20.40	16.26	.80	.80	.20	13.06	85.62	3.93	75.71
	I+II+III			11.70	13.60	11.70	.57	.87	.13	37.67	88.40	6.40	81.23
2	U	3.74	11.21										
	I	3.74	11.21	.00	52.01	29.69	.00	.57	1.00	4.33	77.01	2.65	69.32
	II	3.90	11.02	-.64	22.32	2.22	-.05	.10	1.05	1.79	60.77	.19	10.65
	III	3.13	9.39	2.42	20.10	5.25	.21	.26	.79	2.57	68.75	.56	29.21
	I+II			-.30	26.01	15.96	-.05	.61	1.05	9.10	83.73	2.70	69.68
	I+II+III			.64	17.34	12.39	.16	.71	.84	32.07	87.41	3.96	75.82
3	U	1.11	6.67										
	I	1.11	6.67	.00	58.68	29.69	.00	.51	1.00	7.29	82.19	4.45	77.35
	II	.71	4.24	2.42	20.99	4.65	.36	.16	.64	5.55	79.79	1.10	47.60
	III	1.11	6.67	-2.42	24.34	2.83	-.57	.12	1.57	3.26	72.94	.42	22.99
	I+II			1.21	29.34	17.17	.36	.59	.64	25.92	87.79	8.10	82.96
	I+II+III			.00	19.56	12.39	.00	.43	1.00	31.09	88.16	5.58	79.83
4	U	< .50	< 6.06										
	I	< .50	< 6.06										
	II	< .50	< 6.06										
	III	< .50	< 6.06										
	I+II												
	I+II+III												
5	U	< .50	< 12.12										
	I	< .50	< 12.12										
	II	< .50	< 12.12										
	III	< .50	< 12.12										
	I+II												
	I+II+III												
6	U	< .50	< 24.24										
	I	< .50	< 24.24										
	II	< .50	< 24.24										
	III	< .50	< 24.24										
	I+II												
	I+II+III												
7	U	< .50	< 48.48										
	I	< .50	< 48.48										
	II	< .50	< 48.48										
	III	< .50	< 48.48										
	I+II												
	I+II+III												

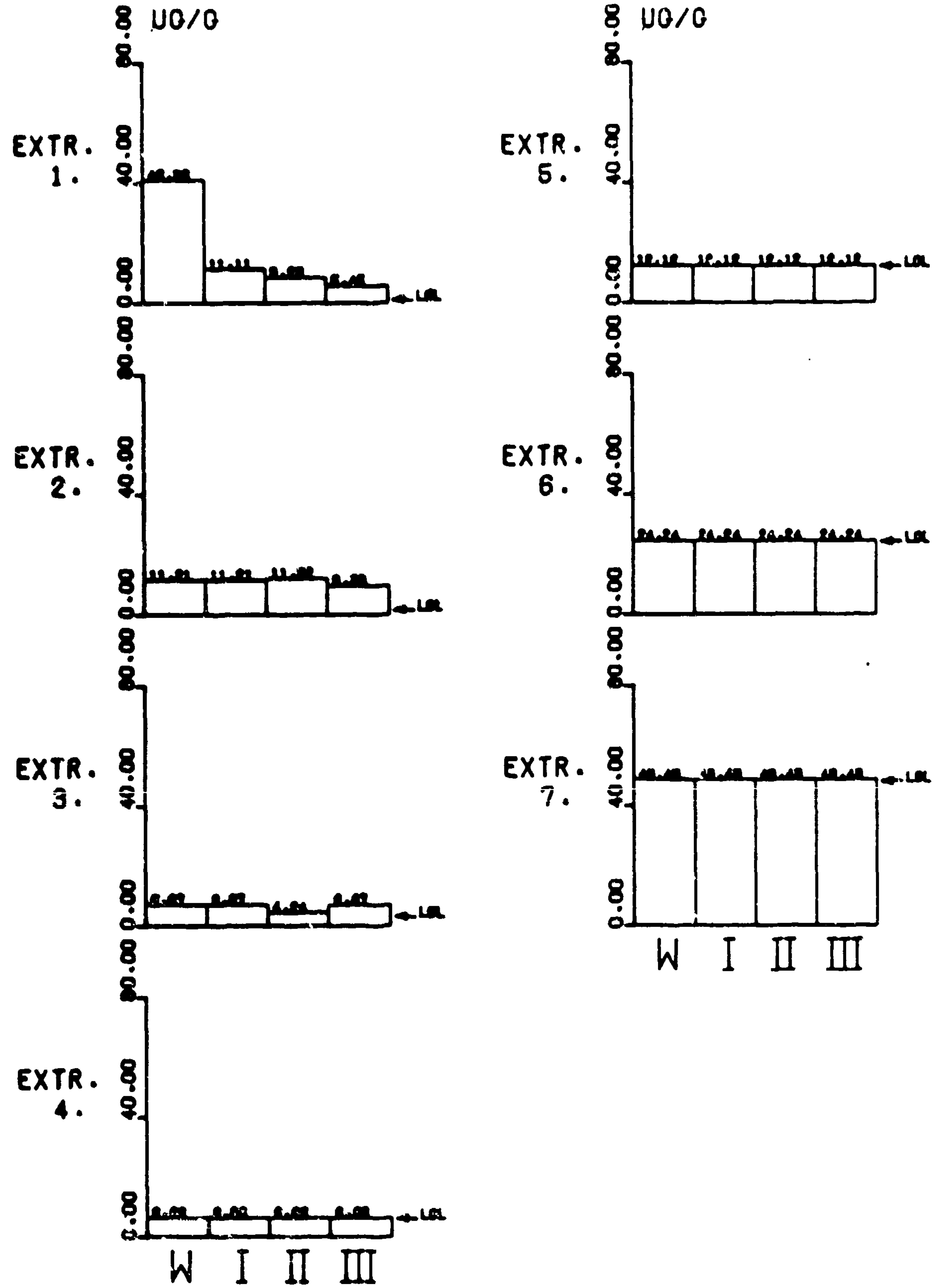

FIGURE 157. WEIGHT OF BORON FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

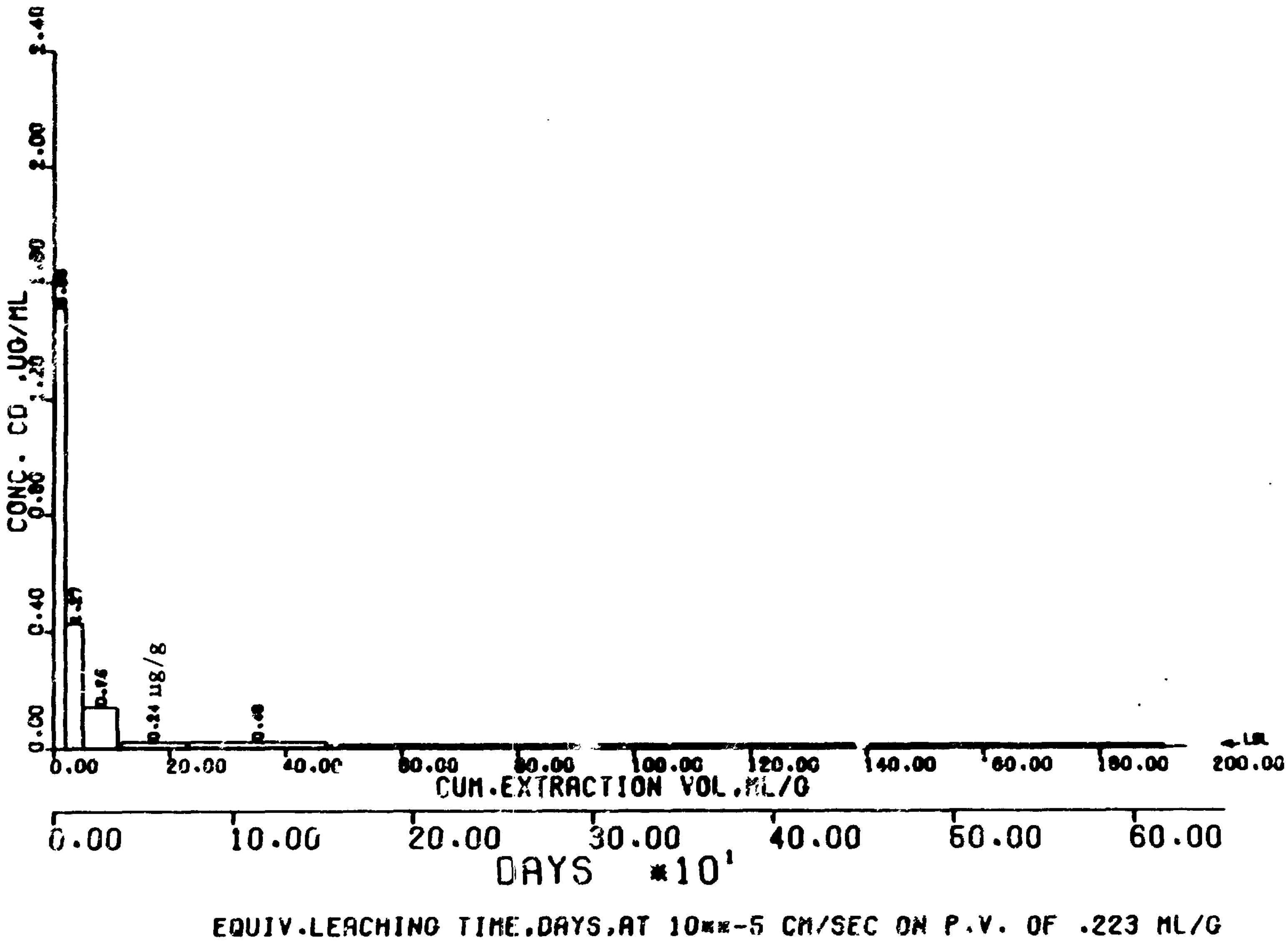

FIGURE 158. EXTRACTION OF CADMIUM FROM OIL RE-REFINING WASTE (A).

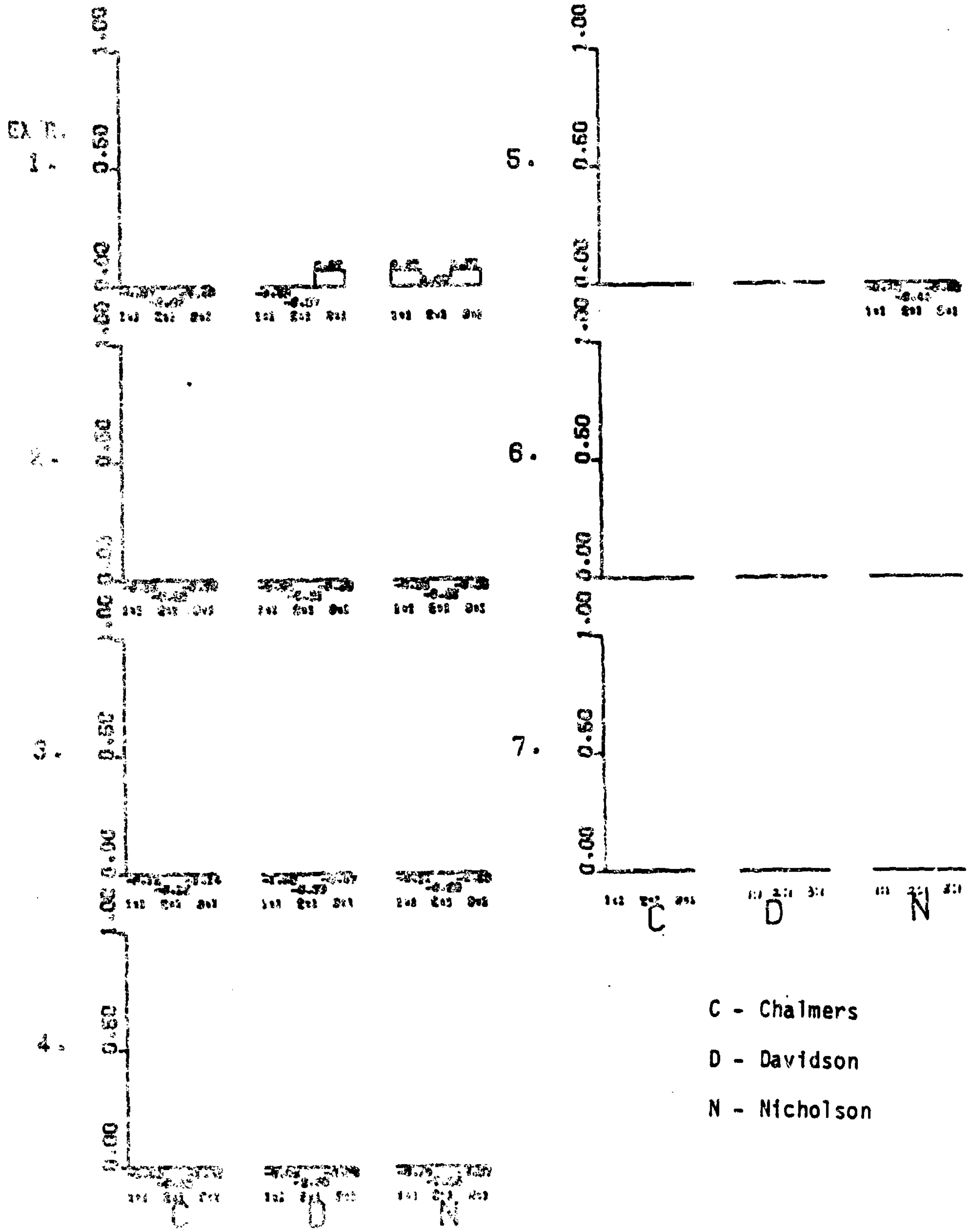

FIGURE 159. COMPARING FRACTION CADMIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 53. CADMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEC.	SOLN ONLY RATIO	SOLN ONLY DEC.
1	W	1.52	3.03										
	I	1.42	3.23	-.20	3.03	-.20	-.07	-.07	1.07	.09	5.27	-.06	-3.58
	II	1.62	3.23	.20	3.23	.00	.00	.00	1.00	.15	8.79	.00	.00
	III	2.12	4.24	-1.01	3.23	-1.01	-.31	-.31	1.31	-.12	-6.86	-.24	-13.39
	I+II			-.10	1.52	-.10	-.07	-.07	1.07	.56	29.09	-.06	-3.58
	I+II+III			-.40	1.51	-.40	-.40	-.40	1.40	.78	37.78	-.29	-15.95
2	W	.42	1.27										
	I	.58	1.73	-.45	4.30	-.66	-.36	-.15	1.36	-.09	-5.18	-.38	-20.81
	II	.78	2.33	-.61	4.96	-.61	-.35	-.12	1.35	-.05	-2.60	-.26	-14.56
	III	1.11	3.33	-1.00	5.57	-2.01	-.43	-.36	1.43	-.45	-24.37	-.60	-31.09
	I+II			-.53	2.15	-.63	-.83	-.29	1.83	.32	17.54	-.54	-28.42
	I+II+III			-.69	1.43	-1.09	-1.62	-.76	2.62	.37	20.22	-.90	-44.47
3	W	.14	.05										
	I	.13	.79	.06	5.15	-.60	.07	-.12	.93	-.12	-6.94	-.75	-37.10
	II	.23	1.39	-.61	5.75	-1.21	-.77	-.21	1.77	-.51	-27.06	-.37	-41.01
	III	.58	3.45	-2.06	6.96	-4.07	-1.48	-.58	2.48	-1.03	-45.95	-1.10	-47.60
	I+II			-.27	2.58	-.90	-.64	-.35	1.64	.14	7.05	-1.30	-52.37
	I+II+III			-.87	1.72	-1.96	-3.07	-1.14	4.07	-.40	-21.75	-1.70	-59.56
4	W	.02	.24										
	I	<.01	<.12	.12	5.39	-.47	.50	-.09	.50	.21	11.79	-3.72	-75.60
	II	.04	.73	-.61	5.07	-1.02	-5.00	-.31	6.00	-1.01	-61.11	-2.50	-68.20
	III	.17	2.06	-1.33	7.69	-5.40	-1.03	-.70	2.03	-2.30	-67.21	-2.62	-69.13
	I+II			-.24	2.70	-1.15	-2.00	-.43	3.00	-.40	-21.92	-3.15	-72.40
	I+II+III			-.61	1.80	-2.57	-7.50	-1.43	8.50	-1.55	-57.19	-3.74	-75.01
5	W	.02	.40	--									
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.40										
	I	.08	3.00										
	II	<.01	<.40										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	W	<.01	<.77										
	I	<.01	<.77										
	II	.05	4.05										
	III	.04	3.00										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

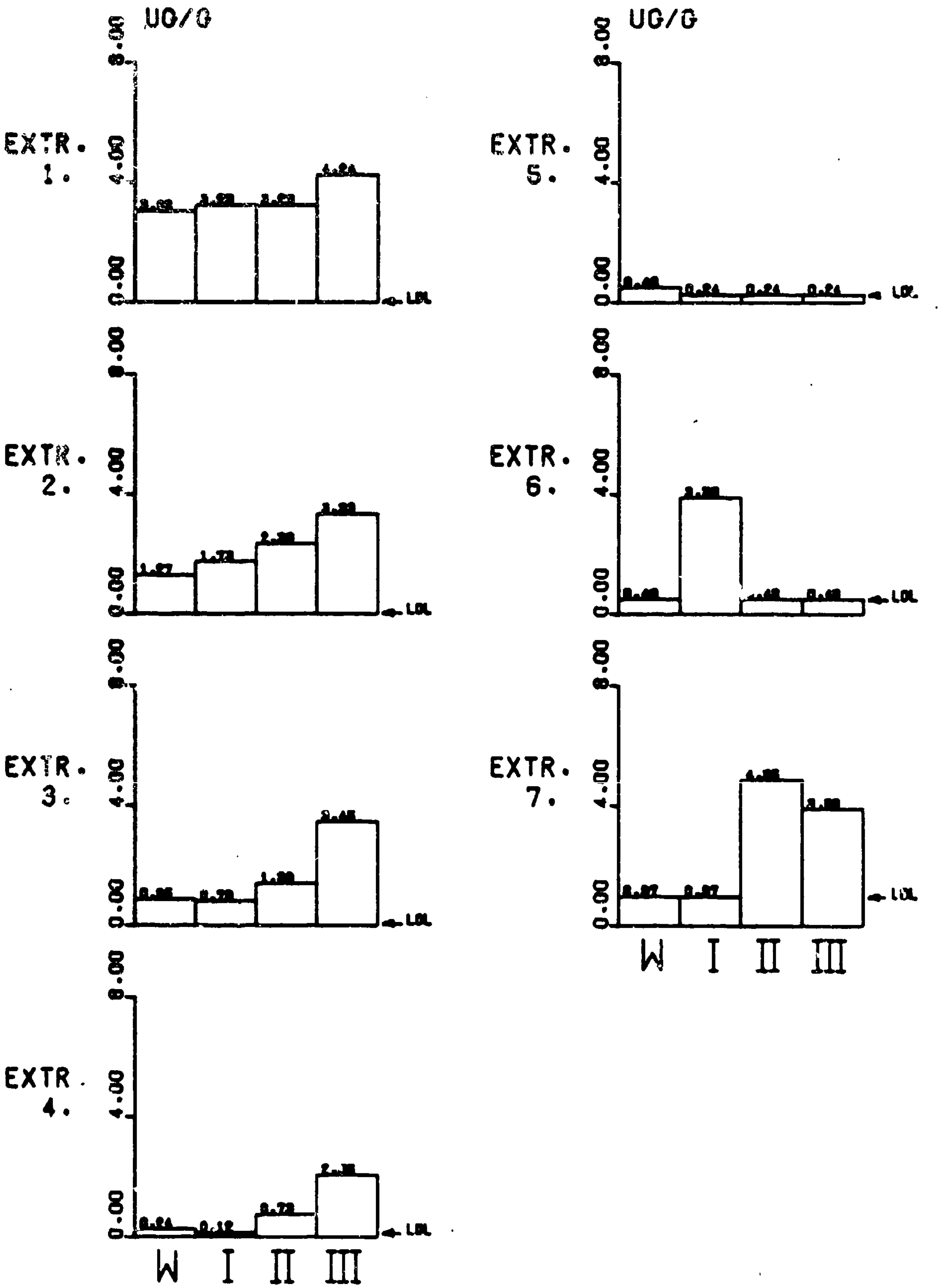

FIGURE 160. WEIGHT OF CADMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 84. CADMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL. SOIL RATIO	INCL. SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	1.52	3.03										
	I	2.02	4.04	-1.01	3.03	-1.01	-.33	-.33	1.33	.11	6.22	-.25	-14.04
	II	2.53	5.05	-1.01	4.04	-1.01	-.25	-.25	1.25	.09	4.98	-.20	-11.31
	III	1.41	2.83	2.22	5.05	2.22	.44	.44	.56	1.30	52.40	.79	38.16
	I+II			-1.01	1.52	-1.01	-.67	-.67	1.67	.75	36.82	-.40	-21.80
	I+II+III			.07	1.01	.07	.07	.07	.93	4.69	77.95	.07	4.09
2	W	.42	1.27										
	I	.58	1.73	-.45	4.30	-1.46	-.36	-.34	1.36	-.01	-.48	-.85	-40.30
	II	.19	.58	1.15	5.77	.14	.67	.02	.33	2.76	70.11	.25	13.80
	III	1.01	3.03	-2.45	5.63	-.23	-4.26	-.04	5.26	.40	21.89	-.08	-4.38
	I+II			.35	2.15	-.66	.55	-.31	.45	7.78	82.67	-2.30	-66.49
	I+II+III			-.59	1.43	-.52	-1.38	-.36	2.38	3.79	75.23	-.51	-27.17
3	W	.14	.85										
	I	.81	4.85	-4.00	5.15	-5.46	-4.71	-1.06	5.71	-.83	-39.62	-1.13	-48.42
	II	.20	1.21	3.64	10.62	3.78	.75	.36	.25	4.31	76.95	3.12	72.21
	III	.28	1.70	-.40	6.84	-.72	-.40	-.10	1.40	.43	23.36	-.42	-22.91
	I+II			-.18	2.58	-.84	-.43	-.33	1.43	3.39	73.58	-1.39	-54.30
	I+II+III			-.28	1.72	-.80	-1.00	-.47	2.00	6.27	80.94	-1.42	-54.78
4	W	.02	.24										
	I	<.01	<12	.12	5.39	-5.34	.50	-.99	.50	-32.12	-88.22	-44.08	-88.70
	II	.04	.48	-.36	10.74	3.41	-3.00	.32	4.00	10.03	84.31	7.04	81.92
	III	.07	.85	-.36	7.32	-1.08	-.75	-.15	1.75	.44	23.52	-1.27	-51.87
	I+II			-.12	2.70	-.96	-1.00	-.36	2.00	7.90	82.80	-3.99	-75.89
	I+II+III			-.20	1.80	-1.00	-2.50	-.56	3.50	11.83	85.17	-3.55	-74.26
5	W	.02	.48										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	.02	1.94										
	I+II												
	I+II+III												

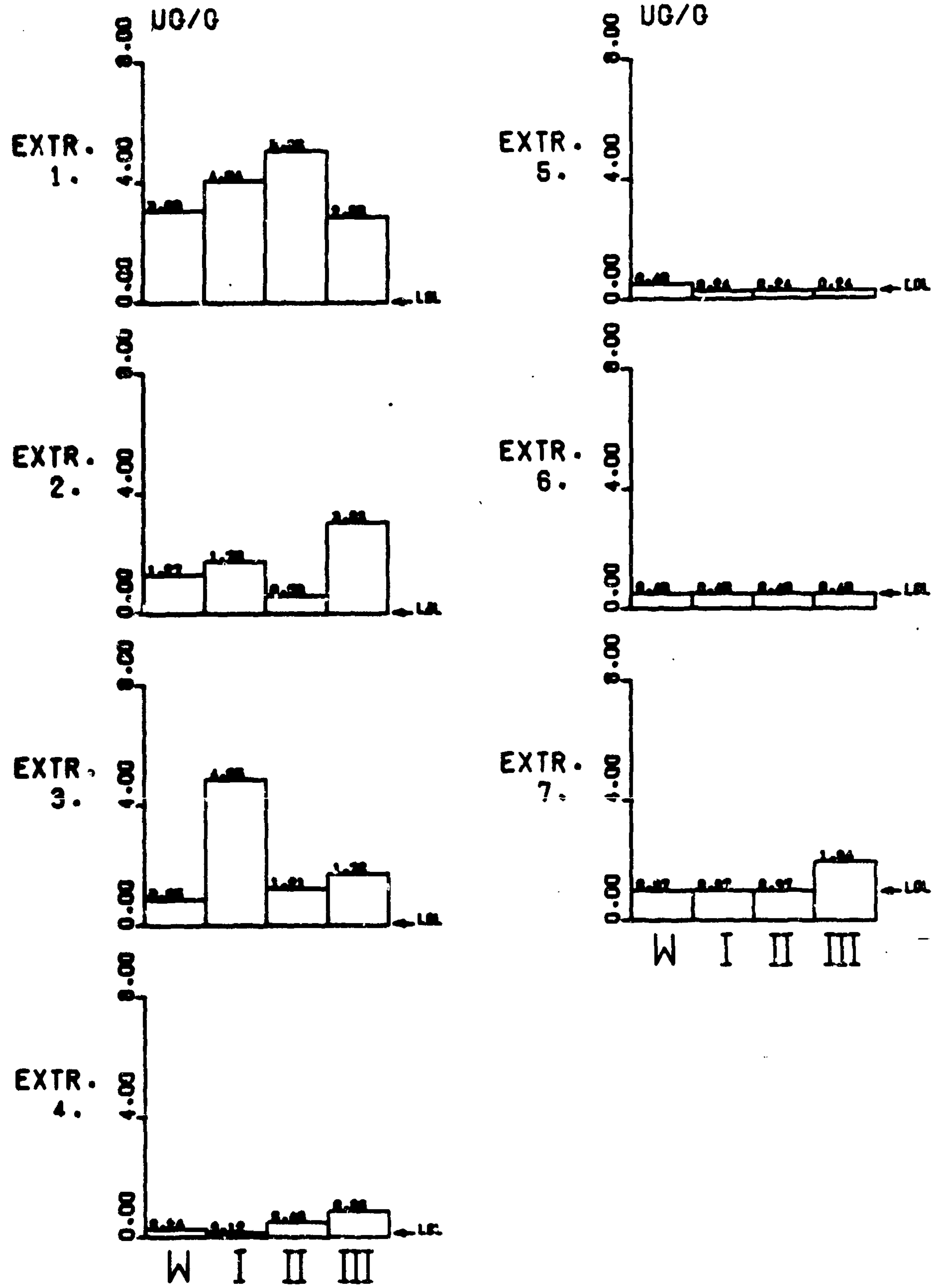

FIGURE 161. WEIGHT OF CADMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 85. CADMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	1.52	3.03										
	I	1.41	2.83	.20	3.03	.20	.07	.07	.93	.25	13.94	.07	4.09
	II	1.52	3.03	-.20	2.83	-.20	-.07	-.07	1.07	.10	5.62	-.07	-3.81
	III	1.41	2.83	.20	3.03	.20	.07	.07	.93	.25	13.94	.07	4.09
	I+II			.00	1.52	.00	.00	.00	1.00	.66	33.43	.00	.00
	I+II+III			.07	1.01	.07	.07	.07	.93	1.66	58.90	.07	4.09
2	W	.42	1.27										
	I	.63	1.00	-.61	4.30	-.40	-.40	-.09	1.40	.05	2.93	-.22	-12.14
	II	.75	2.24	-.36	4.71	-.57	-.19	-.12	1.19	-.03	-1.60	-.25	-14.16
	III	1.01	3.03	-.79	5.27	-.59	-.35	-.11	1.35	-.03	-1.62	-.19	-10.94
	I+II			-.40	2.15	-.40	-.76	-.23	1.76	.46	24.60	-.43	-23.39
	I+II+III			-.59	1.43	-.52	-1.30	-.36	2.30	.97	44.10	-.51	-27.17
3	W	.14	.85										
	I	.17	1.03	-.10	5.15	-.59	-.21	-.12	1.21	-.08	-4.76	-.57	-29.62
	II	.23	1.39	-.36	5.74	-.93	-.35	-.16	1.35	-.31	-17.12	-.67	-33.69
	III	.46	2.79	-1.39	6.67	-1.90	-1.00	-.30	2.00	-.53	-27.96	-.71	-35.38
	I+II			-.27	2.58	-.76	-.64	-.29	1.64	.35	19.19	-1.09	-47.39
	I+II+III			-.65	1.72	-1.16	-2.29	-.68	3.29	.36	19.83	-1.25	-51.42
4	W	.02	.24										
	I	.04	.40	-.24	5.39	-.83	-1.00	-.15	2.00	-.60	-34.10	-1.71	-59.66
	II	.05	.61	-.12	6.22	-1.05	-.25	-.17	1.25	-.91	-42.25	-1.73	-60.02
	III	.12	1.45	-.85	7.27	-2.03	-1.40	-.39	2.40	-1.60	-58.01	-1.94	-62.70
	I+II			-.18	2.70	-.94	-1.50	-.35	2.50	.20	11.33	-3.10	-72.12
	I+II+III			-.40	1.80	-1.57	-5.00	-.87	6.00	-.14	-8.00	-3.24	-72.83
5	W	.02	.40										
	I	<.01	<.24	.24	5.00	-.59	.50	-.10	.50	-.35	-19.49	-2.42	-67.52
	II	.05	1.21	-.97	6.46	-2.02	-4.00	-.31	5.00	-1.25	-51.43	-1.67	-59.04
	III	.02	.40	.73	8.40	-2.10	.60	-.25	.40	-3.30	-73.15	-4.33	-77.01
	I+II			-.36	2.94	-1.30	-1.50	-.44	2.50	-.50	-26.56	-2.15	-65.06
	I+II+III			.00	1.96	-1.57	.00	-.80	1.00	-.43	-23.06	-9.71	-84.12
6	W	<.01	<.40										
	I	.03	1.45										
	II	.04	1.94										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

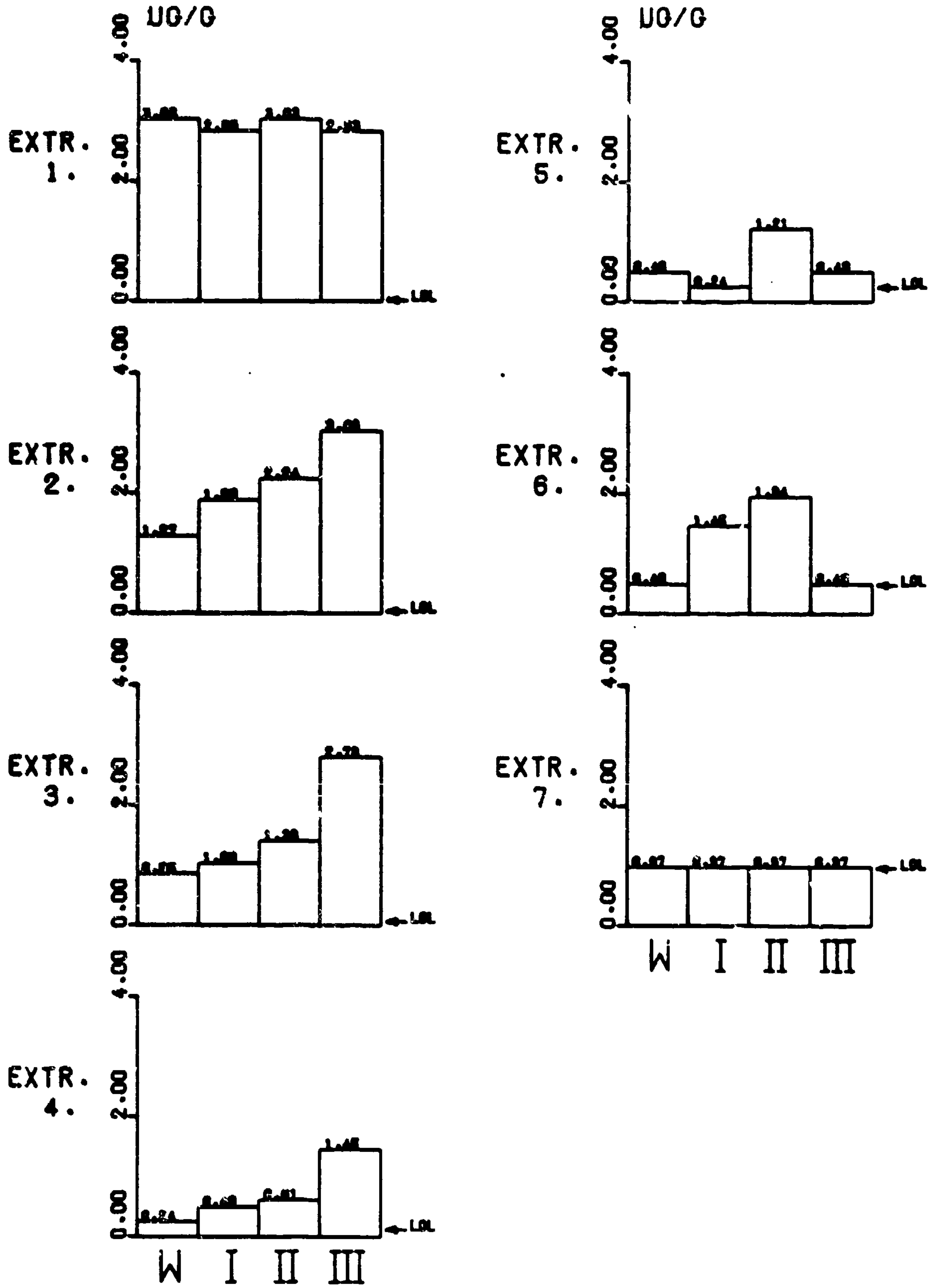

FIGURE 162. WEIGHT OF CADMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

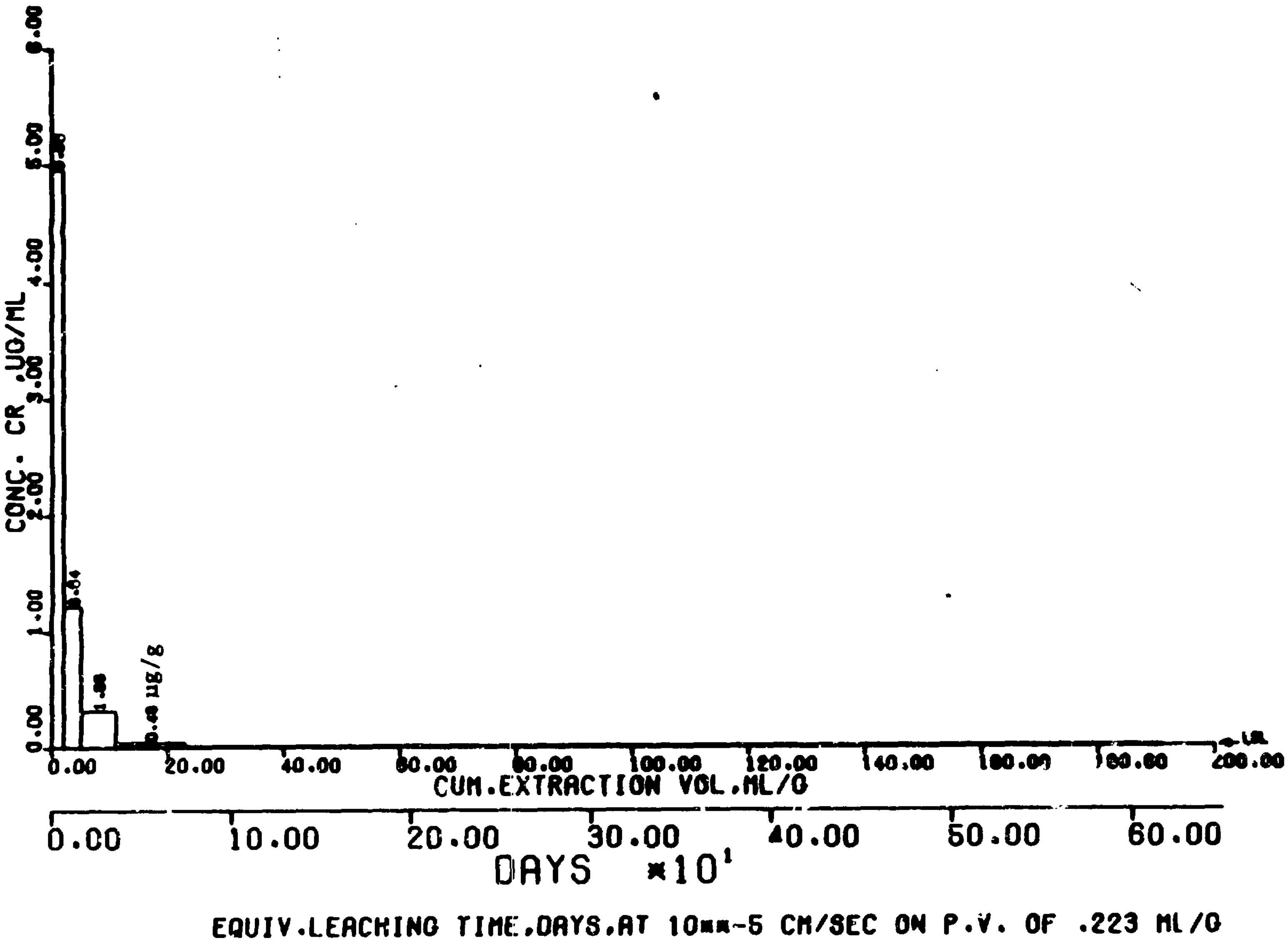

FIGURE 163. EXTRACTION OF CHROMIUM FROM OIL RE-REFINING WASTE (A).

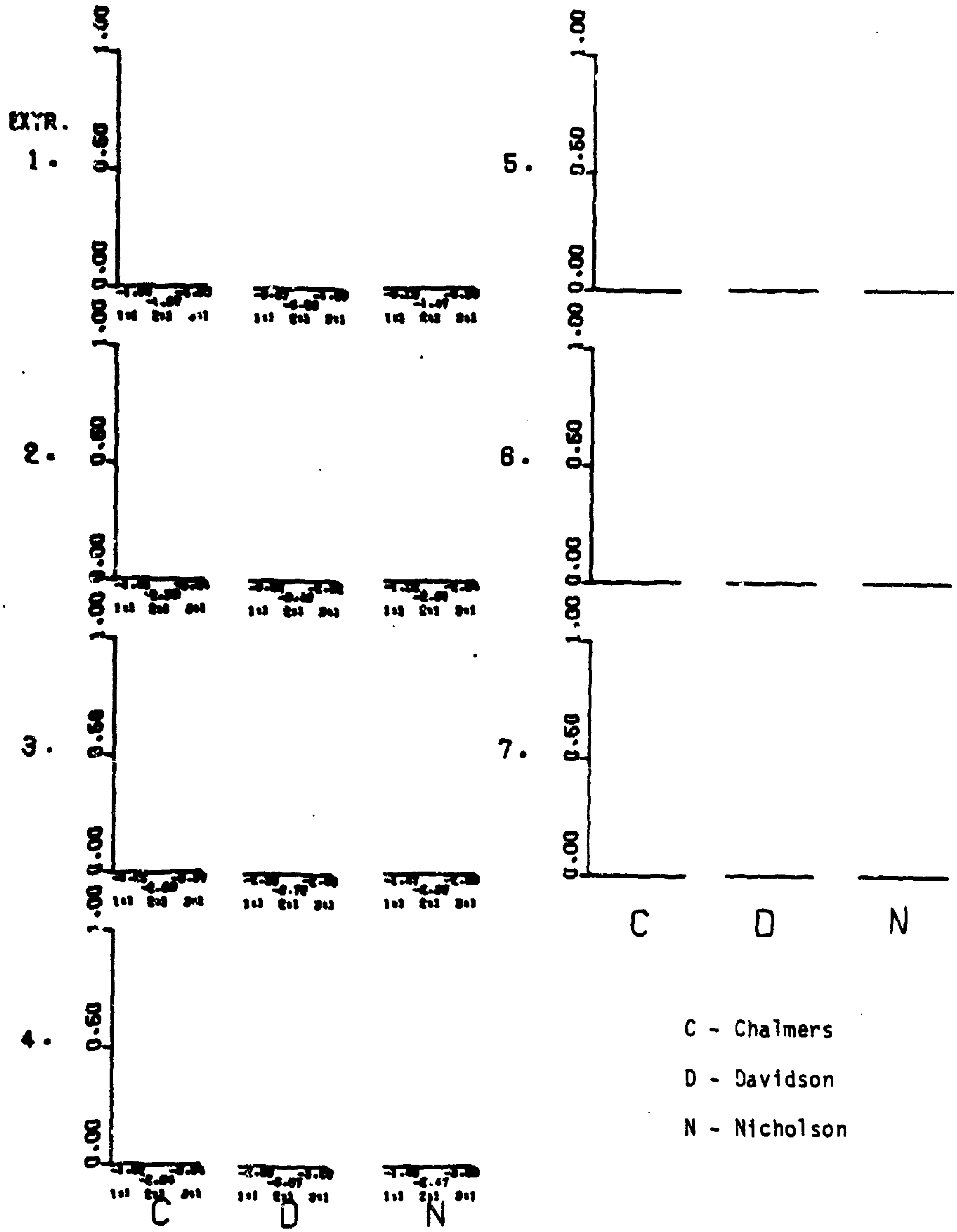

FIGURE 164. COMPARING FRACTION CHROMIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 86. CHROMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.55	9.90										
	I	13.33	26.66	-16.77	9.90	-16.77	-1.69	-1.69	2.69	.42	22.05	-.63	-32.16
	II	11.72	23.43	3.23	26.66	3.23	.12	.12	.00	1.33	53.12	.14	7.05
	III	26.46	52.92	-29.49	23.43	-29.49	-1.26	-1.26	2.26	-.03	-1.61	-.56	-29.13
	I+II			-6.77	4.95	-6.77	-1.37	-1.37	2.37	4.20	76.61	-.50	-30.01
	I+II+III			-14.34	3.30	-14.34	-4.35	-4.35	5.35	3.95	75.79	-.81	-39.11
2	W	1.21	3.64										
	I	2.32	6.97	-3.33	13.53	-23.10	-.92	-1.49	1.92	1.13	48.59	-2.00	-70.00
	II	7.07	21.21	-14.24	33.63	-11.01	-2.04	-.33	3.04	.00	38.70	-.52	-27.43
	III	10.50	31.51	-10.30	44.64	-39.79	-.49	-.09	1.49	-.37	-23.52	-1.26	-51.63
	I+II			-8.79	6.77	-15.55	-4.83	-2.30	5.83	3.01	75.31	-1.47	-55.71
	I+II+III			-9.29	4.51	-23.63	-7.67	-5.24	8.67	5.75	80.13	-2.25	-66.04
3	W	.36	1.00										
	I	.90	5.00	-4.90	15.41	-24.10	-2.13	-1.56	3.13	.66	33.57	-4.10	-76.29
	II	1.02	10.91	-5.03	39.51	-16.04	-.06	-.41	1.06	1.10	47.64	-1.47	-55.70
	III	4.05	29.09	-18.10	55.55	-57.97	-1.67	-1.04	2.67	-1.03	-45.86	-1.99	-63.36
	I+II			-4.51	7.71	-20.07	-4.86	-2.60	5.81	6.59	81.37	-3.60	-74.80
	I+II+III			-9.07	5.14	-32.70	-14.40	-6.37	15.40	5.29	79.30	-3.37	-73.49
4	W	.04	.40										
	I	.05	.61	-.12	15.90	-24.22	-.25	-1.52	1.25	6.24	80.89	-39.97	-88.57
	II	.19	2.30	-1.70	40.12	-17.74	-2.00	-.40	3.00	4.46	77.36	-7.70	-82.60
	III	.67	8.00	-5.70	57.85	-63.67	-2.47	-1.10	3.47	-4.46	-77.36	-7.96	-82.84
	I+II			-.91	7.95	-20.98	-3.75	-2.64	4.75	30.42	88.12	-18.22	-86.86
	I+II+III			-2.50	5.30	-35.21	-15.50	-6.64	16.50	18.30	86.87	-13.20	-85.67
5	W	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.40										
	I	<.01	<.40										
	II	<.01	<.40										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

END OF PROGRAM

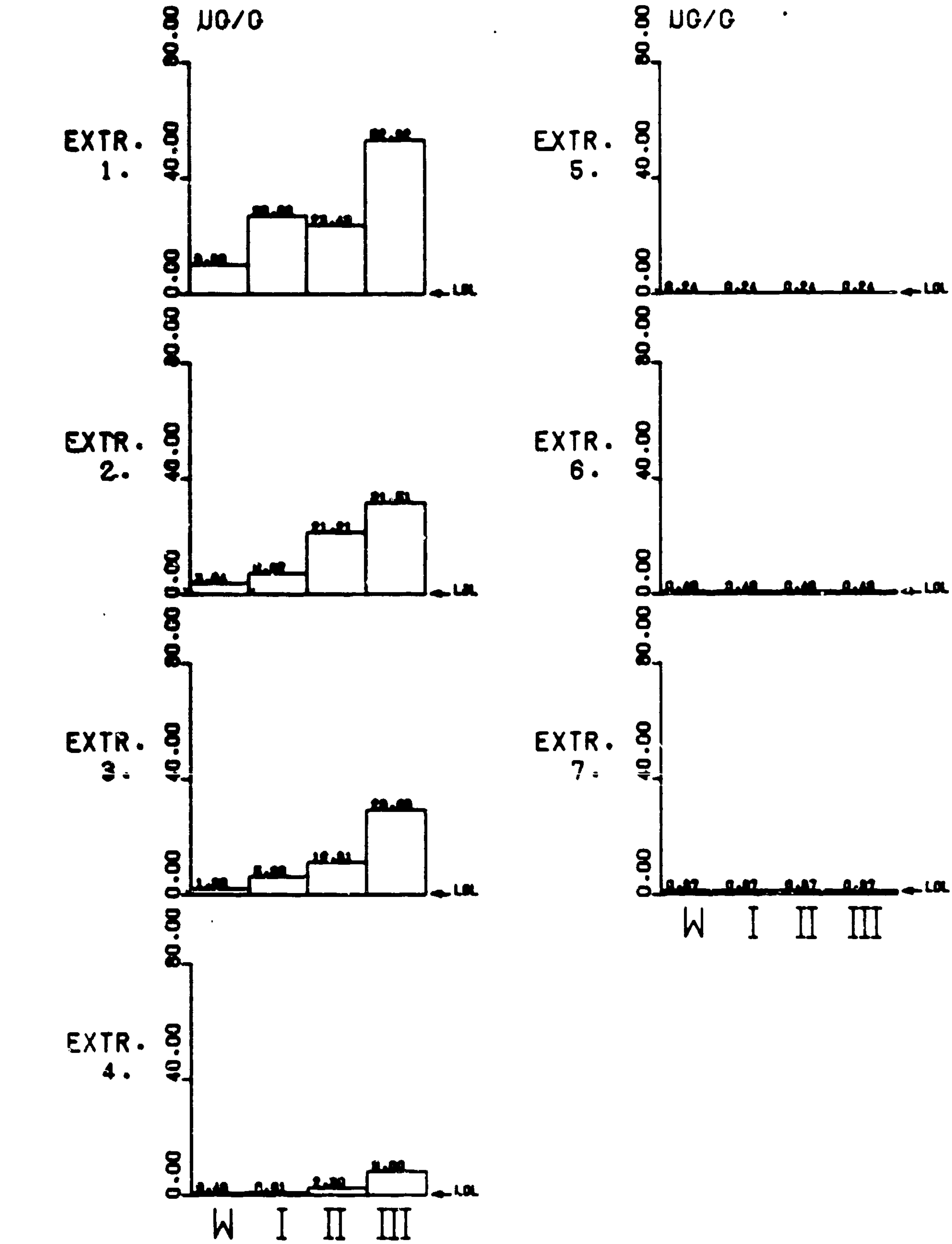

FIGURE 165. WEIGHT OF CHROMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 87. CHROMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	0	4.95	9.90										
	I	8.28	16.56	-6.67	9.90	-6.67	-.67	-.67	1.67	1.93	62.50	-.40	-21.92
	II	8.08	16.16	.40	16.56	.40	.02	.02	.98	2.41	67.49	.03	1.43
	III	13.84	27.67	-11.51	16.16	-11.51	-.71	-.71	1.71	.98	44.38	-.42	-22.59
	I+II			-3.13	4.95	-3.13	-.63	-.63	1.63	9.17	83.77	-.39	-21.18
	I+II+III			-5.93	3.30	-5.93	-1.00	-1.00	2.00	11.91	85.20	-.64	-32.71
2	0	1.21	3.64										
	I	2.83	8.48	-4.05	13.53	-11.51	-1.33	-.85	2.33	3.19	72.61	-1.36	-53.62
	II	.91	2.73	5.76	25.05	6.16	.68	.25	.32	16.91	86.51	2.26	66.12
	III	5.76	17.27	-14.54	18.09	-26.06	-5.33	-1.38	6.33	.73	35.99	-1.51	-56.46
	I+II			.45	6.77	-2.60	.25	-.40	.75	54.66	88.95	-1.96	-63.00
	I+II+III			-4.55	4.51	-10.47	-3.75	-2.32	4.75	18.30	86.87	-1.82	-61.28
3	0	.31	1.88										
	I	4.95	29.69	-27.02	15.41	-39.33	-14.01	-2.55	15.01	-.02	-1.41	-1.32	-52.95
	II	1.41	8.48	21.21	54.74	27.37	.71	.50	.29	7.78	82.67	3.23	72.78
	III	2.73	16.36	-7.00	27.37	-33.94	-.93	-1.24	1.93	.29	15.91	-2.07	-64.26
	I+II			-3.30	7.71	-5.90	-3.52	-.78	4.52	16.79	86.59	-1.41	-54.65
	I+II+III			-4.83	5.14	-15.30	-7.71	-2.98	8.71	18.43	86.89	-2.80	-70.38
4	0	.04	.48										
	I	.08	.97	-.40	15.90	-39.01	-1.00	-2.50	2.00	-1.25	-51.39	-41.06	-88.60
	II	.19	2.30	-1.33	55.71	26.04	-1.37	.47	2.38	28.07	87.96	11.31	84.95
	III	.54	6.42	-4.12	29.67	-38.06	-1.79	-1.28	2.79	.00	4.83	-5.92	-80.42
	I+II			-.91	7.95	-6.89	-3.75	-.87	4.75	61.07	89.06	-5.98	-80.51
	I+II+III			-1.98	5.30	-17.28	-12.25	-3.26	13.25	46.01	88.75	-8.07	-82.94
5	0	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	0	<.01	<.40										
	I	<.01	<.40										
	II	<.01	<.40										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	0	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

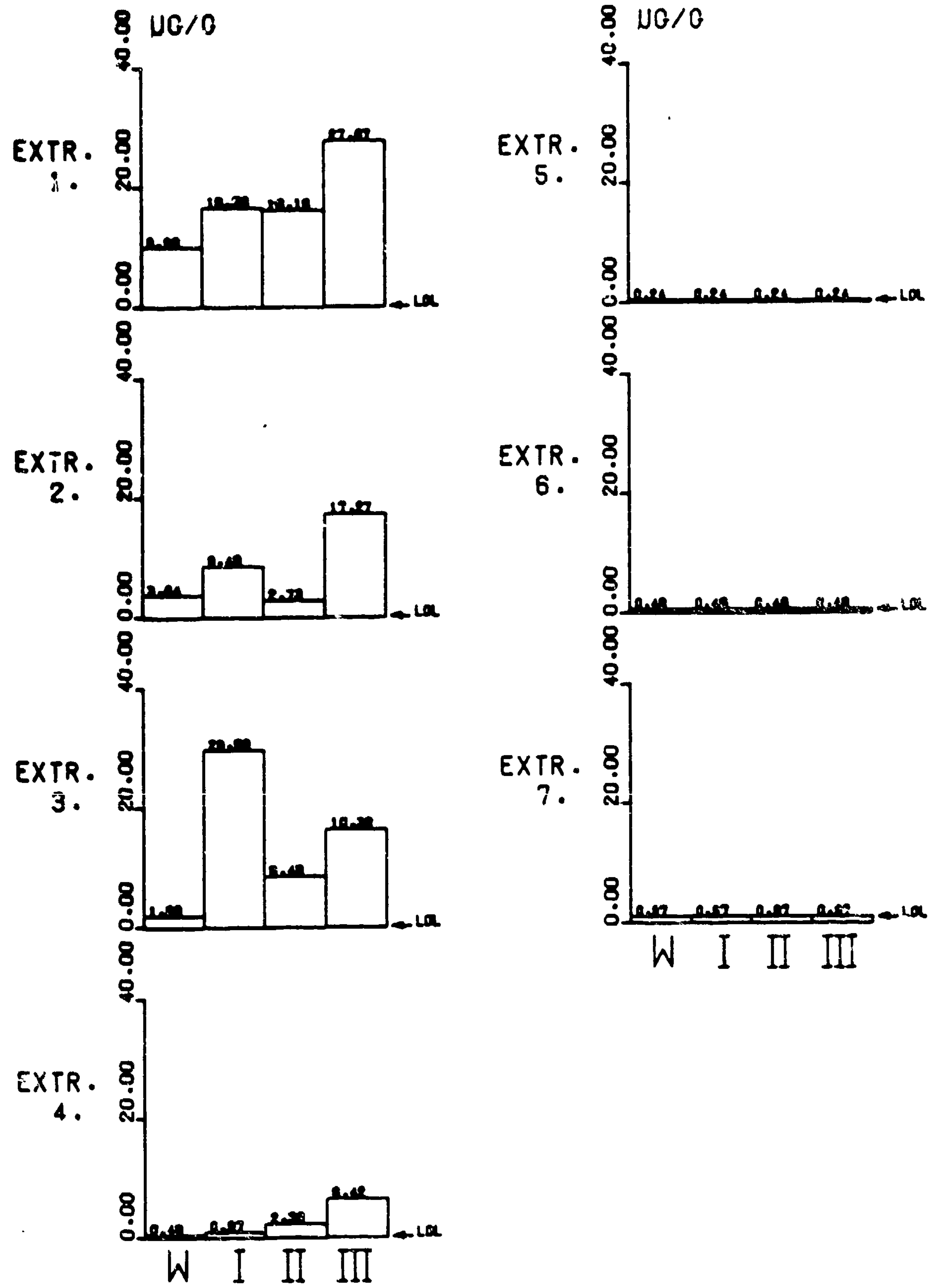

FIGURE 166. WEIGHT OF CHROMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 98. CHROMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON (A).

EXT. NO.	LAYER	AMT PENETR. UG/ML	AMT PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.95	9.90										
	I	[illegible]	19.59	-7.70	9.90	-9.70	-.98	-.98	1.98	1.19	49.94	-.49	-26.33
	II	12.22	24.44	-4.85	19.59	-4.85	-.25	-.25	1.25	1.15	49.03	-.20	-11.22
	III	7.68	15.35	9.09	24.44	9.09	.37	.37	.63	2.74	69.96	.59	30.63
	I+II			-7.27	4.95	-7.27	-1.47	-1.47	2.47	4.01	70.24	-.60	-30.75
	I+II+III			-1.82	3.30	-1.82	-.55	-.55	1.55	18.99	86.99	-.36	-19.56
2	W	1.21	3.64										
	I	3.94	11.82	-8.10	13.53	-17.80	-2.25	-1.32	3.25	1.28	52.00	-1.51	[illegible].53
	II	5.45	16.36	-4.54	31.41	-9.39	-.38	-.30	1.38	1.44	55.27	-.57	-29.86
	III	8.58	25.75	-9.39	40.00	-.30	-.57	-.01	1.57	1.27	51.77	-.61	-.67
	I+II			-6.36	6.77	-13.64	-3.50	-2.01	4.50	6.40	81.12	-1.67	-59.04
	I+II+III			-7.37	4.51	-9.19	-6.08	-2.04	7.08	10.46	84.54	-1.07	-46.95
3	W	.31	1.00										
	I	1.11	6.67	-4.79	15.41	-22.66	-2.55	-1.47	3.55	1.55	57.18	-3.40	-73.61
	II	1.92	10.71	-4.24	38.00	-13.63	-.64	-.36	1.64	1.78	60.61	-1.25	-51.34
	III	3.33	20.00	-9.09	51.71	-9.39	-.83	-.18	1.83	1.18	49.73	-.47	-25.16
	I+II			-4.51	7.71	-10.15	-4.81	-2.34	5.81	8.77	83.50	-3.33	-73.27
	I+II+III			-6.04	5.14	-15.23	-9.65	-2.96	10.65	12.57	85.45	-2.20	-66.36
4	W	.04	.48										
	I	.69	1.99	-.61	15.90	-23.27	-1.25	-1.46	2.25	8.92	83.60	-21.33	-87.32
	II	.29	3.51	-2.42	39.17	-16.06	-2.22	-.41	3.22	4.82	78.28	-4.57	-77.65
	III	.87	10.42	-6.91	55.23	-16.30	-1.97	-.30	2.97	1.60	58.07	-1.56	-57.40
	I+II			-1.52	7.95	-19.66	-6.25	-2.47	7.25	26.37	87.83	-11.19	-84.87
	I+II+III			-3.31	5.30	-18.54	-20.50	-3.50	21.50	23.16	87.53	-5.34	-79.39
5	W	< .01	< .24										
	I	< .01	< .24										
	II	< .01	< .24										
	III	< .01	< .24										
	I+II												
	I+II+III												
6	W	< .01	< .48										
	I	< .01	< .48										
	II	< .01	< .48										
	III	< .01	< .48										
	I+II												
	I+II+III												
7	W	< .01	< .97										
	I	< .01	< .97										
	II	< .01	< .97										
	III	< .01	< .97										
	I+II												
	I+II+III												

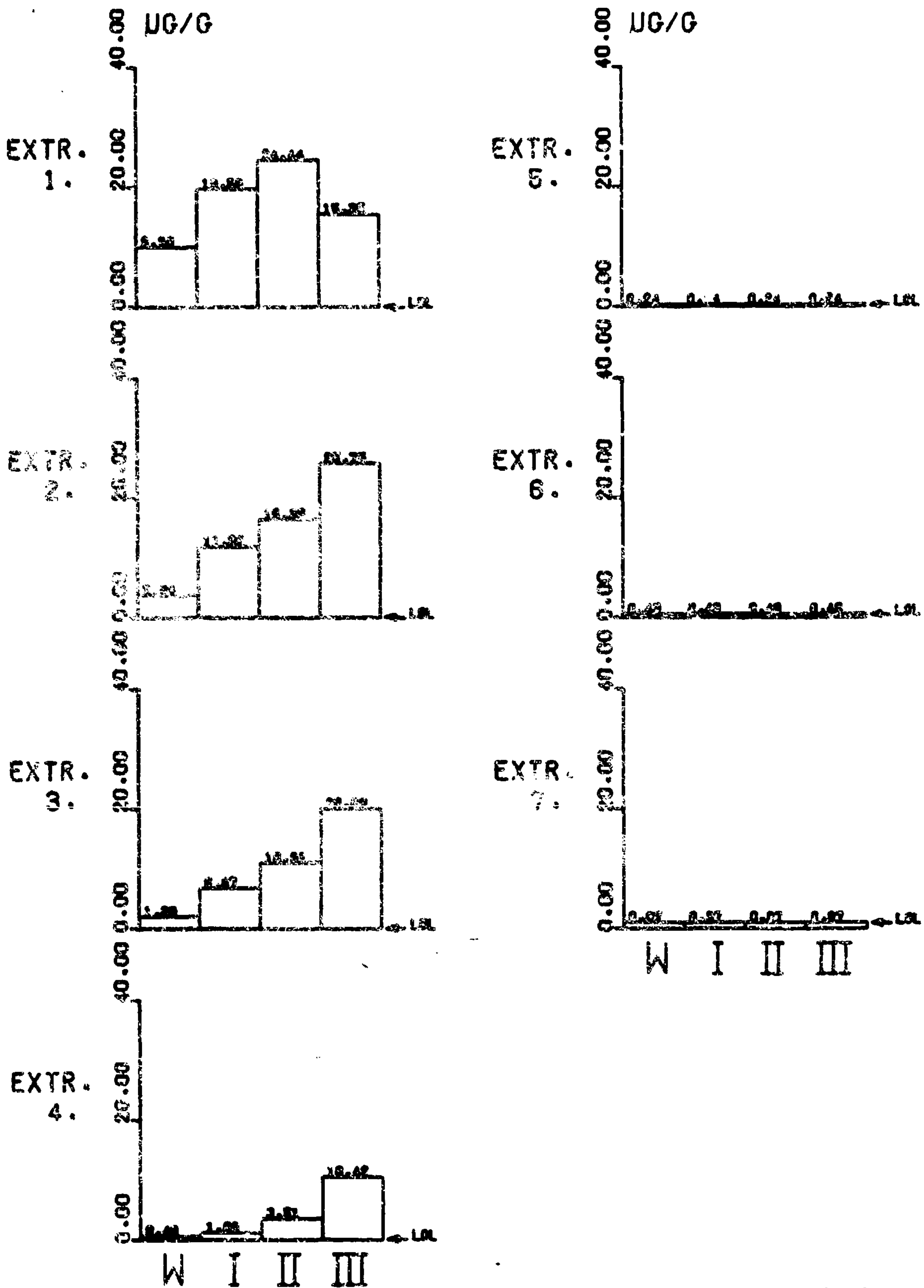

FIGURE 167. WEIGHT OF CHROMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

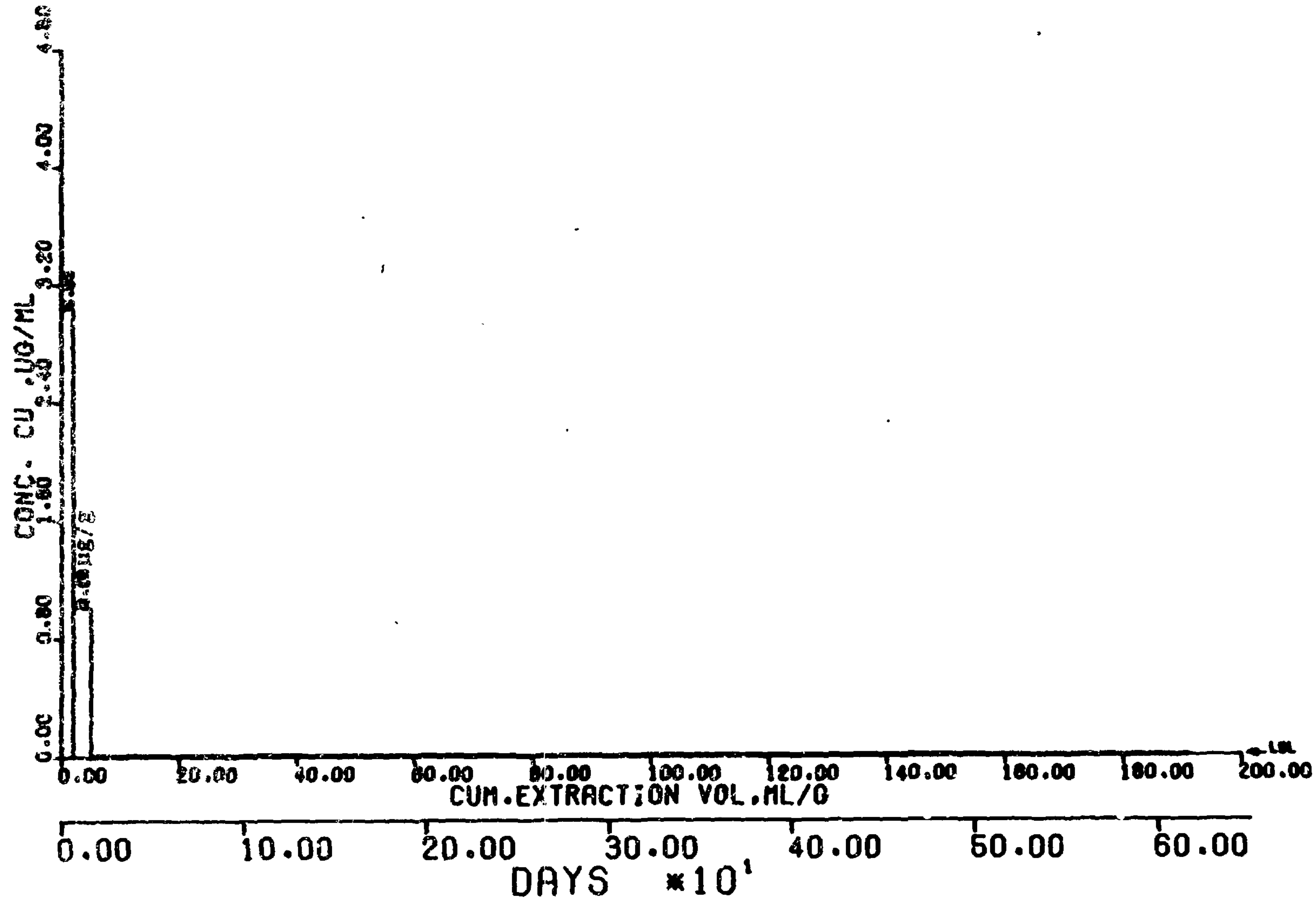

FIGURE 168. EXTRACTION OF COPPER FROM OIL RE-REFINING WASTE (A).

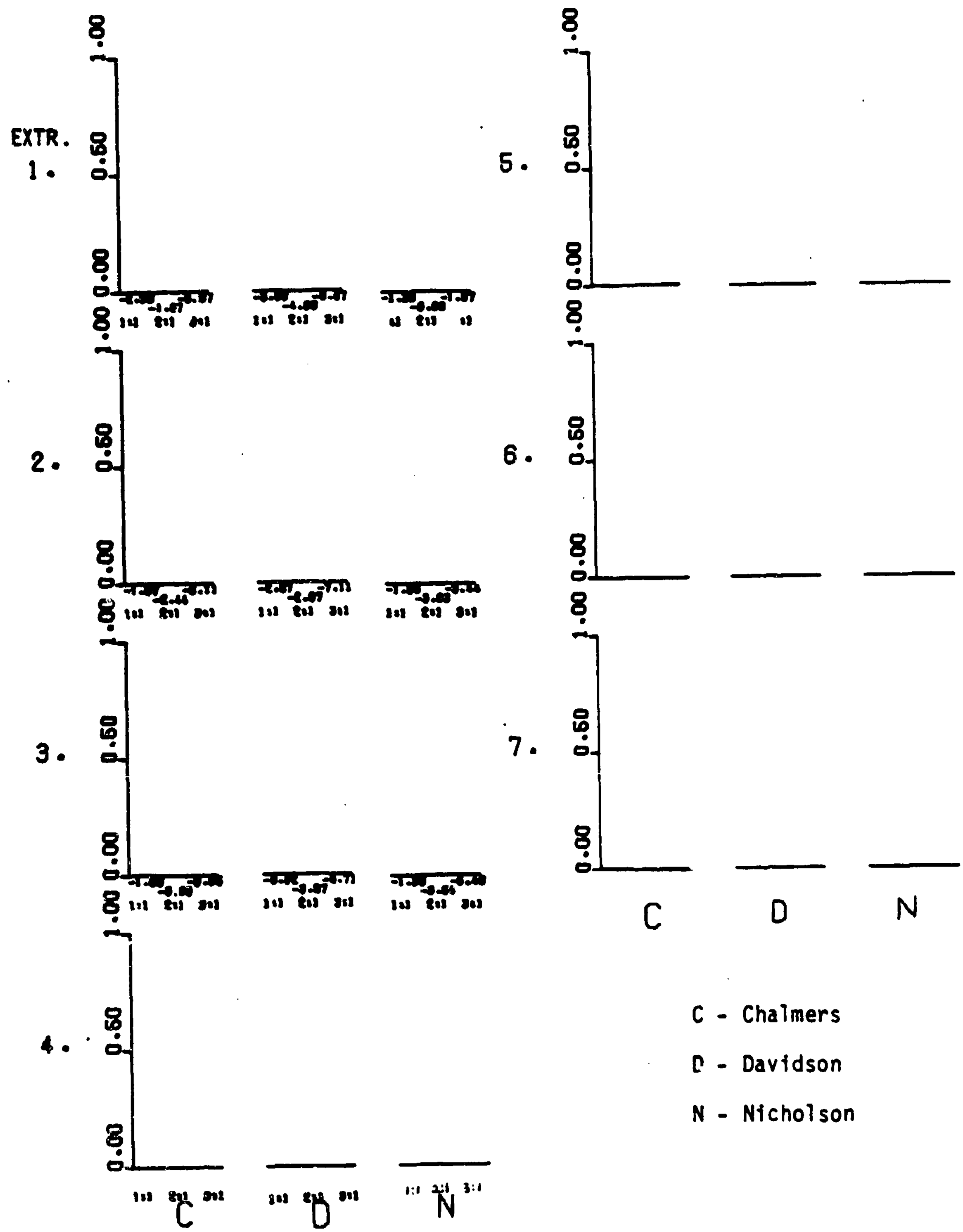

FIGURE 169. COMPARING FRACTION COPPER RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 89. COPPER FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	3.03	6.06										
	I	9.09	18.18	-12.12	6.06	-12.12	-2.00	-2.00	3.00	.50	26.79	-.67	-33.69
	II	8.08	16.16	2.02	18.18	2.02	.11	.11	.89	1.44	55.20	.13	7.13
	III	20.20	40.40	-24.24	16.16	-24.24	-1.50	-1.50	2.50	-.07	-4.16	-.60	-30.96
	I+II			-5.05	3.03	-5.05	-1.67	-1.67	2.67	4.65	77.86	-.63	-32.01
	I+II+III			-11.45	2.02	-11.45	-5.67	-5.67	6.67	3.90	75.60	-.85	-40.36
2	W	1.01	3.03										
	I	2.02	6.06	-3.03	9.09	-15.15	-1.00	-1.67	2.00	1.01	45.42	-2.50	-68.20
	II	5.05	15.15	-9.09	2[illegible].24	-7.07	-1.50	-.29	2.50	.94	43.21	-.47	-25.02
	III	8.08	24.24	-9.09	31.31	-33.33	-.60	-1.06	1.60	-.50	-26.39	-1.30	-53.97
	I+II			-6.06	4.55	-11.11	-4.00	-2.44	5.00	4.16	76.47	-1.47	-55.71
	I+II+III			-7.07	3.03	-18.52	-7.00	-6.11	8.00	5.62	79.90	-2.29	-66.43
3	W	<.01	<.06										
	I	<.01	<.06	.00	9.15	-15.15	.00	-1.66	1.00	102.50	89.44	-252.50	-89.77
	II	1.01	6.06	-6.00	24.30	-13.07	-100.00	-.54	101.	1.36	53.63	-2.16	-65.12
	III	3.03	18.18	-12.12	37.37	-45.45	-2.00	-1.22	3.00	-1.33	-53.03	-2.50	-68.20
	I+II			-3.00	4.57	-14.11	-100.00	-3.08	101.	9.40	83.93	-4.66	-77.80
	I+II+III			-6.04	3.05	-24.56	-302.00	-8.05	303.	6.49	81.24	-4.05	-76.14
4	W	<.01	<.12										
	I	<.01	<.12										
	II	<.01	<.12										
	III	<.01	<.12										
	I+II												
	I+II+III												
5	W	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.96										
	I	<.01	<.96										
	II	<.01	<.96										
	III	<.01	<.96										
	I+II												
	I+II+III												

The remainder of the table was not calculated because the concentrations were below the detection limit.

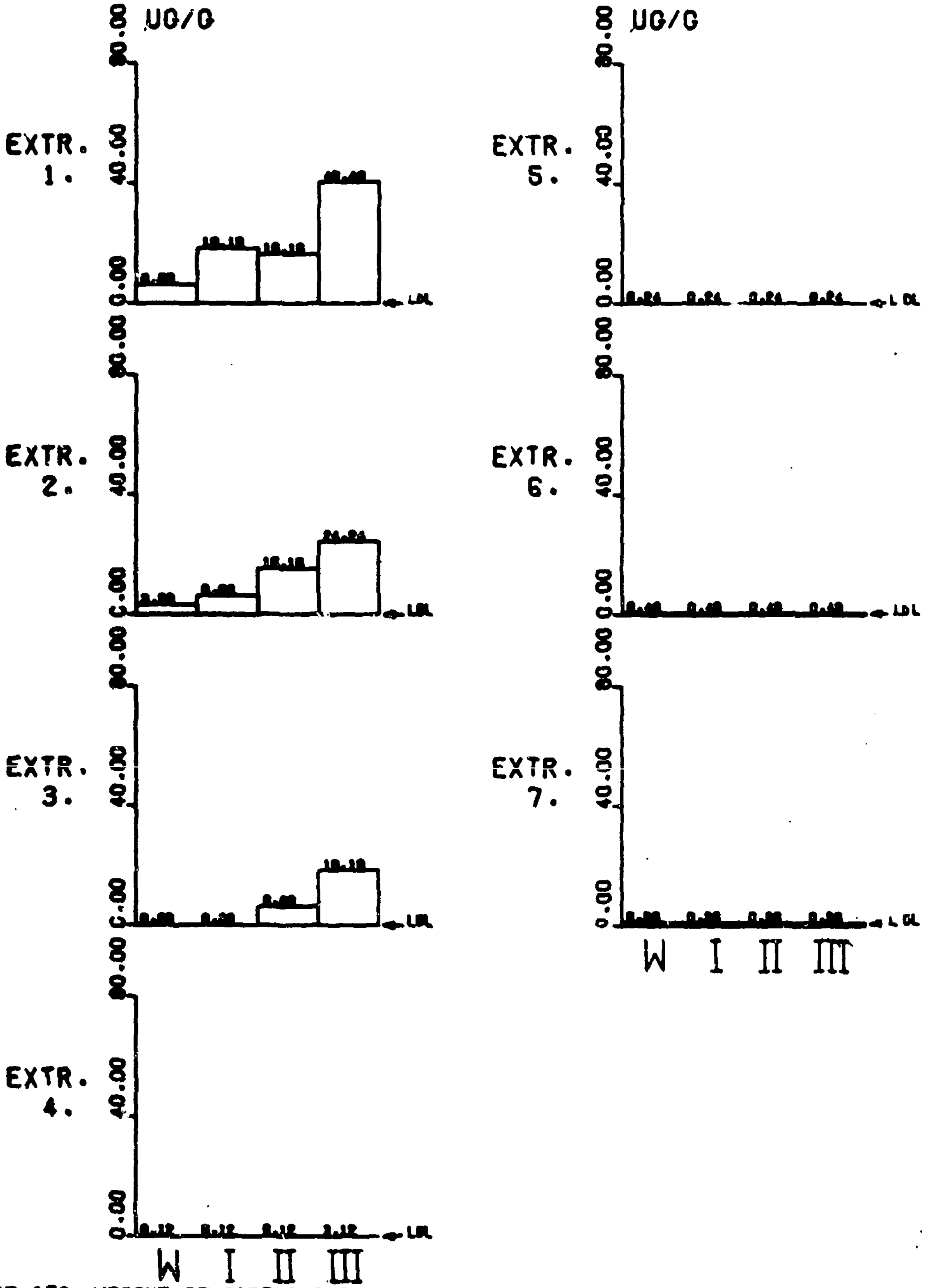

FIGURE 170. WEIGHT OF COPPER FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 90. COPPER FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A)..

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	3.03	6.06										
	I	12.12	24.24	-18.18	6.06	-18.18	-3.00	-3.00	4.00	2.34	66.82	-.75	-36.87
	II	15.15	30.30	-6.06	24.24	-6.06	-.25	-.25	1.25	2.27	66.21	-.20	-11.31
	III	23.23	46.46	-16.16	30.30	-16.16	-.53	-.53	1.53	1.26	51.61	-.35	-19.18
	I+II			-12.12	3.03	-12.12	-4.00	-4.00	5.00	9.07	83.71	-.80	-38.66
	I+II+III			-13.47	2.02	-13.47	-6.67	-6.67	7.67	13.62	85.80	-.87	-41.01
2	W	1.01	3.03										
	I	3.03	9.09	-6.06	9.09	-24.24	-2.00	-2.67	3.00	5.56	79.81	-2.67	-69.44
	II	1.01	3.03	6.06	33.33	.00	.67	.00	.33	24.69	87.68	.00	.00
	III	9.09	27.27	-24.24	33.33	-40.40	-8.00	-1.22	9.00	1.26	51.59	-1.40	-55.98
	I+II			.00	4.55	-12.12	.00	-2.67	1.00	90.75	89.37	-8.00	-82.87
	I+II+III			-8.08	3.03	-21.55	-8.03	-7.11	9.00	22.32	87.43	-2.37	-67.13
3	W	<.01	<.06										
	I	6.06	36.36	-36.30	9.15	-60.54	-605.00	-6.62	606.	.39	21.41	-1.67	-59.01
	II	2.02	12.12	24.24	69.69	24.24	.67	.35	.33	8.17	83.02	2.00	63.43
	III	4.04	24.24	-12.12	45.45	-52.52	-1.00	-1.16	2.00	.92	42.59	-2.17	-65.22
	I+II			-6.03	4.57	-18.15	-201.00	-3.97	202.	21.69	87.36	-3.00	-71.54
	I+II+III			-8.06	3.05	-29.61	-403.00	-9.71	404.	24.11	87.62	-3.66	-74.74
4	W	<.01	<.12										
	I	<.01	<.12										
	II	<.01	<.12										
	III	1.01	12.12										
	I+II												
	I+II+III												
5	W	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.96										
	I	<.01	<.96										
	II	<.01	<.96										
	III	<.01	<.96										
	I+II												
	I+II+III												

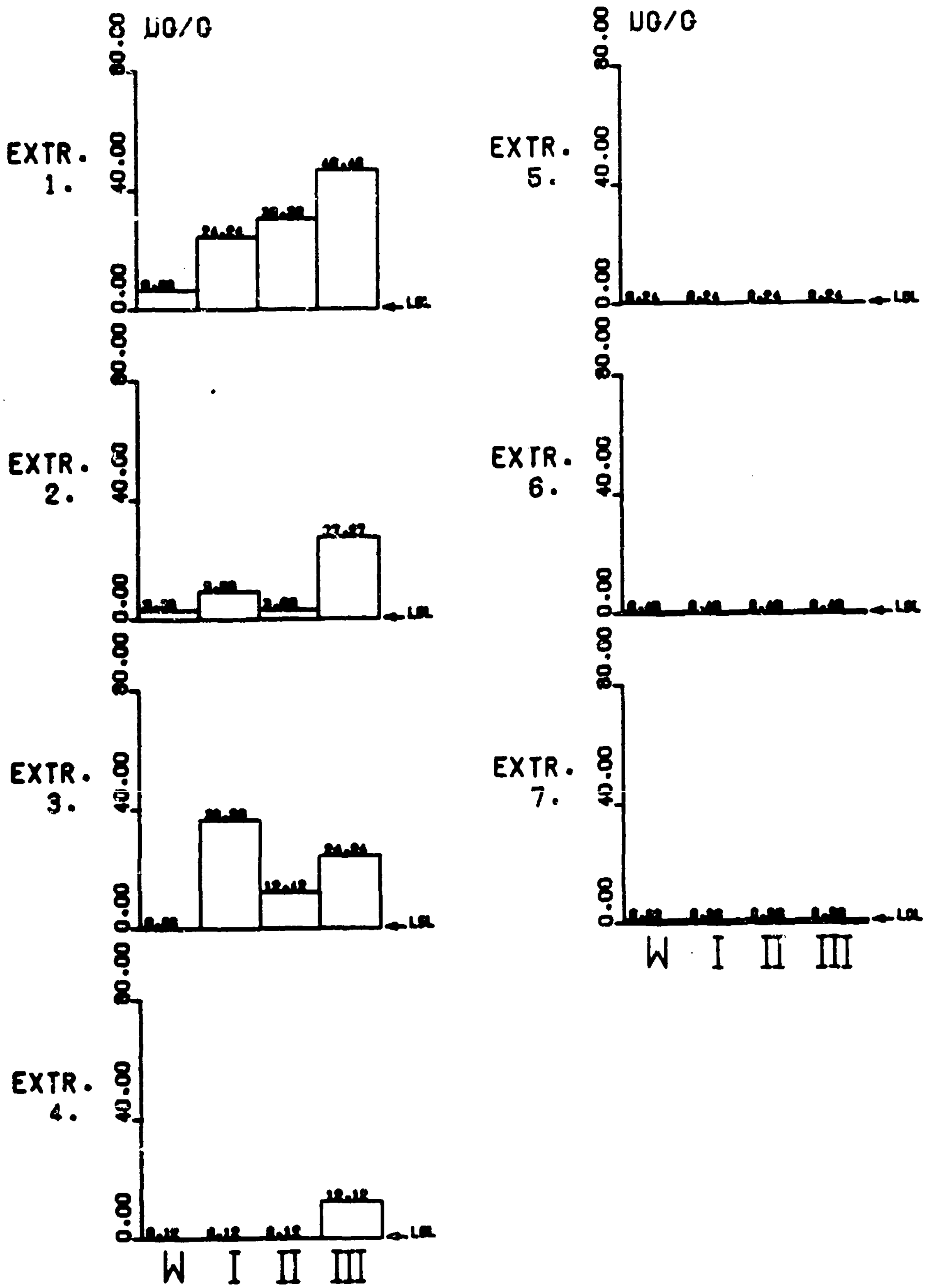

FIGURE 171. WEIGHT OF COPPER FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 91. COPPER FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	0	3.03	6.06										
	I	7.07	14.14	-0.00	6.06	-0.00	-1.33	-1.33	2.33	1.18	49.61	-.57	-29.74
	II	12.12	24.24	-10.10	14.14	-10.10	-.71	-.71	1.71	.60	31.06	-.42	-22.62
	III	0.00	16.16	0.00	24.24	0.00	.33	.33	.67	2.03	63.76	.50	26.57
	I+II			-9.09	3.03	-9.09	-3.00	-3.00	4.00	3.33	73.27	-.75	-36.87
	I+II+III			-3.37	2.02	-3.37	-1.67	-1.67	2.67	13.13	85.65	-.63	-32.11
2	0	1.01	3.03										
	I	3.03	9.09	-6.06	9.09	-14.14	-2.00	-1.56	3.00	1.16	49.28	-1.56	-57.26
	II	4.04	12.12	-3.03	23.23	-13.13	-.33	-.57	1.33	.95	43.67	-1.08	-47.29
	III	0.00	24.24	-12.12	36.36	-4.04	-1.00	-.11	2.00	.85	40.44	-.17	-9.46
	I+II			-4.55	4.55	-13.64	-3.00	-3.00	4.00	5.90	80.38	-2.25	-66.04
	I+II+III			-7.07	3.03	-10.44	-7.00	-3.44	8.00	7.88	82.77	-1.29	-52.25
3	0	<.01	<.06										
	I	<.01	<.06	.00	9.15	-14.14	.00	-1.55	1.00	176.00	89.67	-235.67	-89.76
	II	1.01	6.06	-6.00	23.29	-19.13	-100.00	-.82	101.	.92	42.59	-3.16	-72.42
	III	3.03	18.18	-12.12	42.42	-16.16	-2.00	-.38	3.00	.47	25.16	-.89	-41.63
	I+II			-3.00	4.57	-16.64	-100.00	-3.64	303.	10.81	84.72	-5.49	-79.68
	I+II+III			-6.04	3.05	-16.40	-302.00	-5.40	314.	9.51	84.00	-2.72	-69.81
4	0	<.01	<.12										
	I	<.01	<.12										
	II	<.01	<.12										
	III	1.01	12.12										
	I+II												
	I+II+III												
5	0	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	0	<.01	<.40										
	I	<.01	<.40										
	II	<.01	<.40										
	III	<.01	<.40										
	I+II												
	I+II+III												
7	0	<.01	<.96										
	I	<.01	<.96										
	II	<.01	<.96										
	III	<.01	<.96										
	I+II												
	I+II+III												

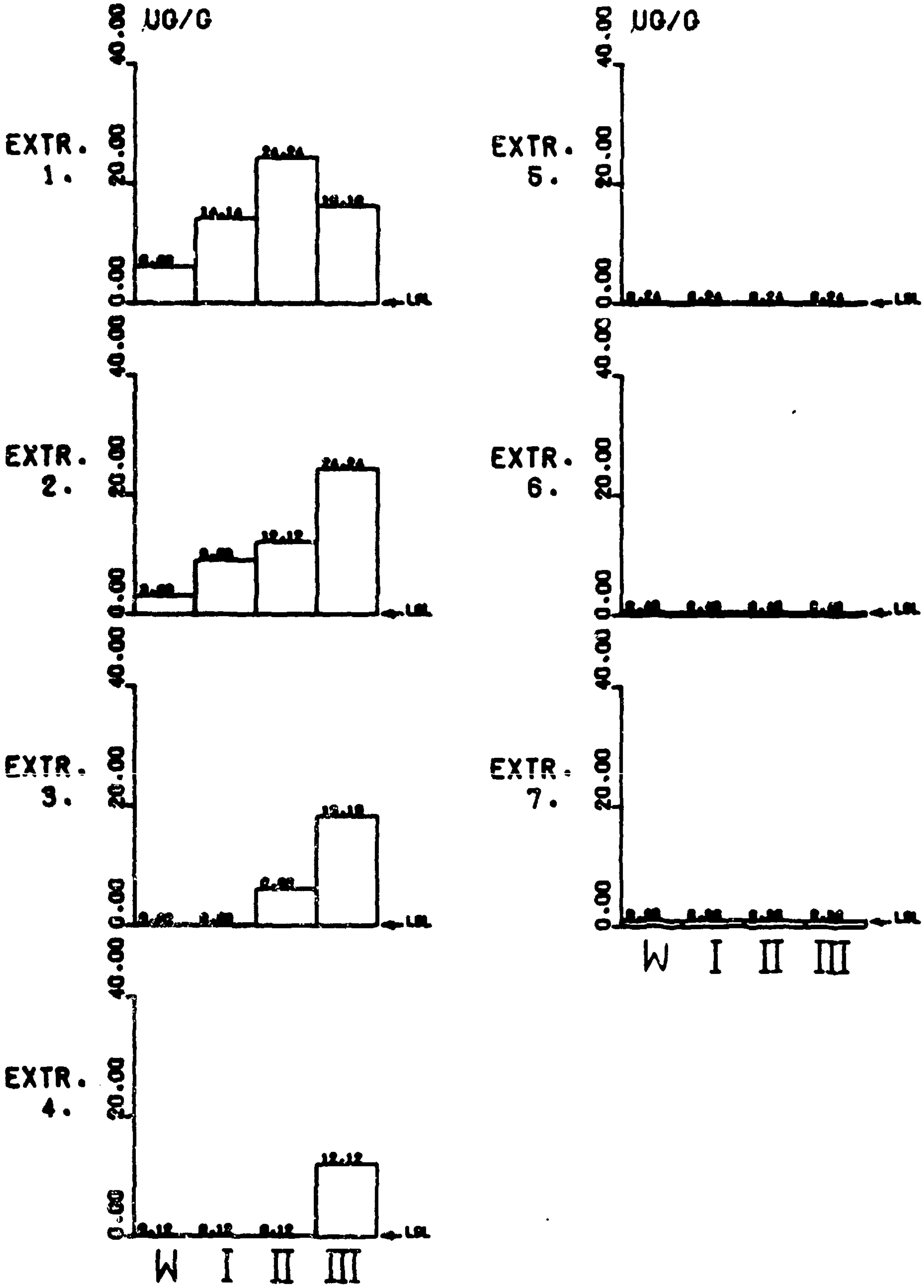

FIGURE 172. WEIGHT OF COPPER FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

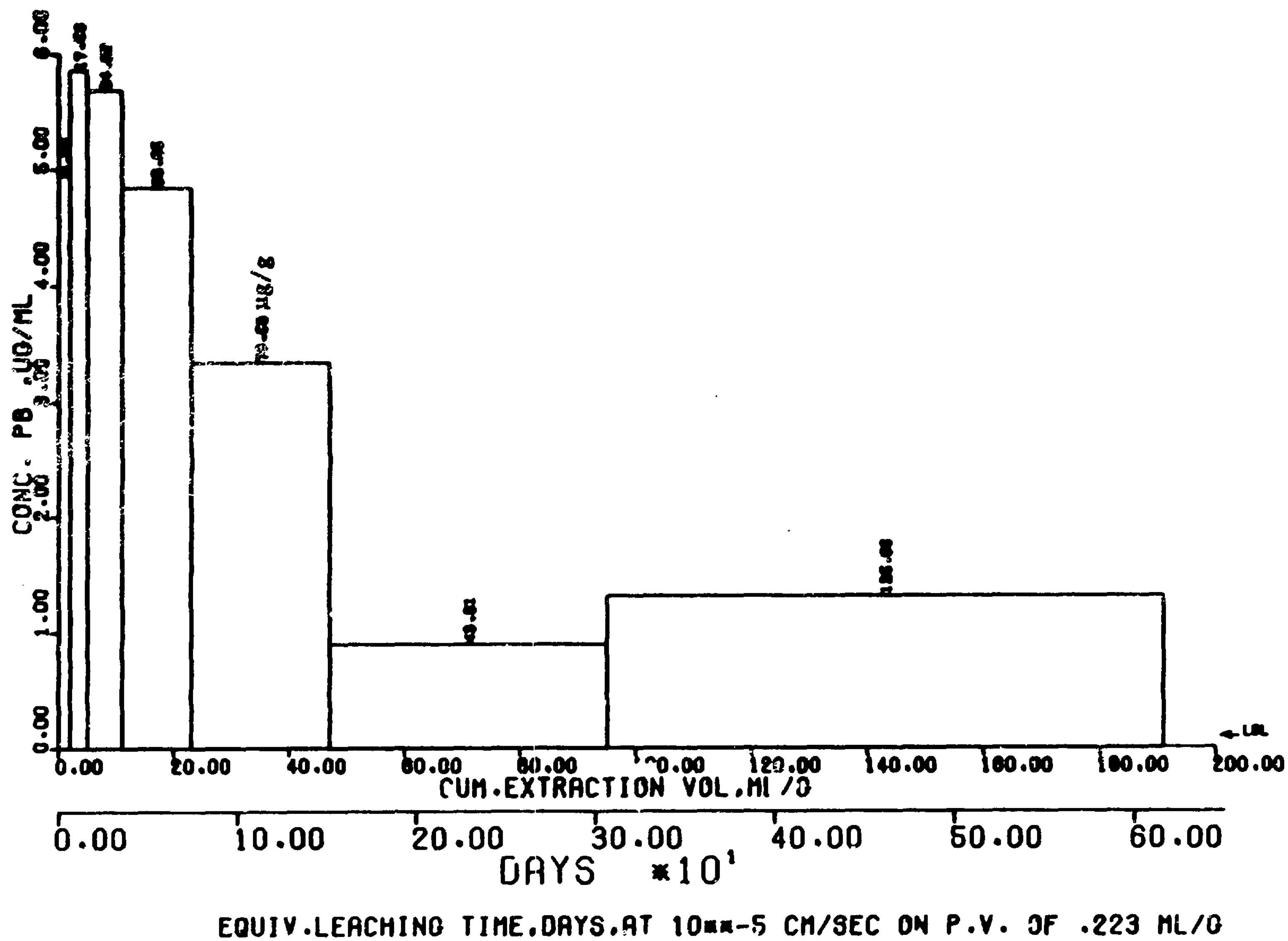

FIGURE 173. EXTRACTION OF LEAD FROM OIL RE-REFINING WASTE (A).

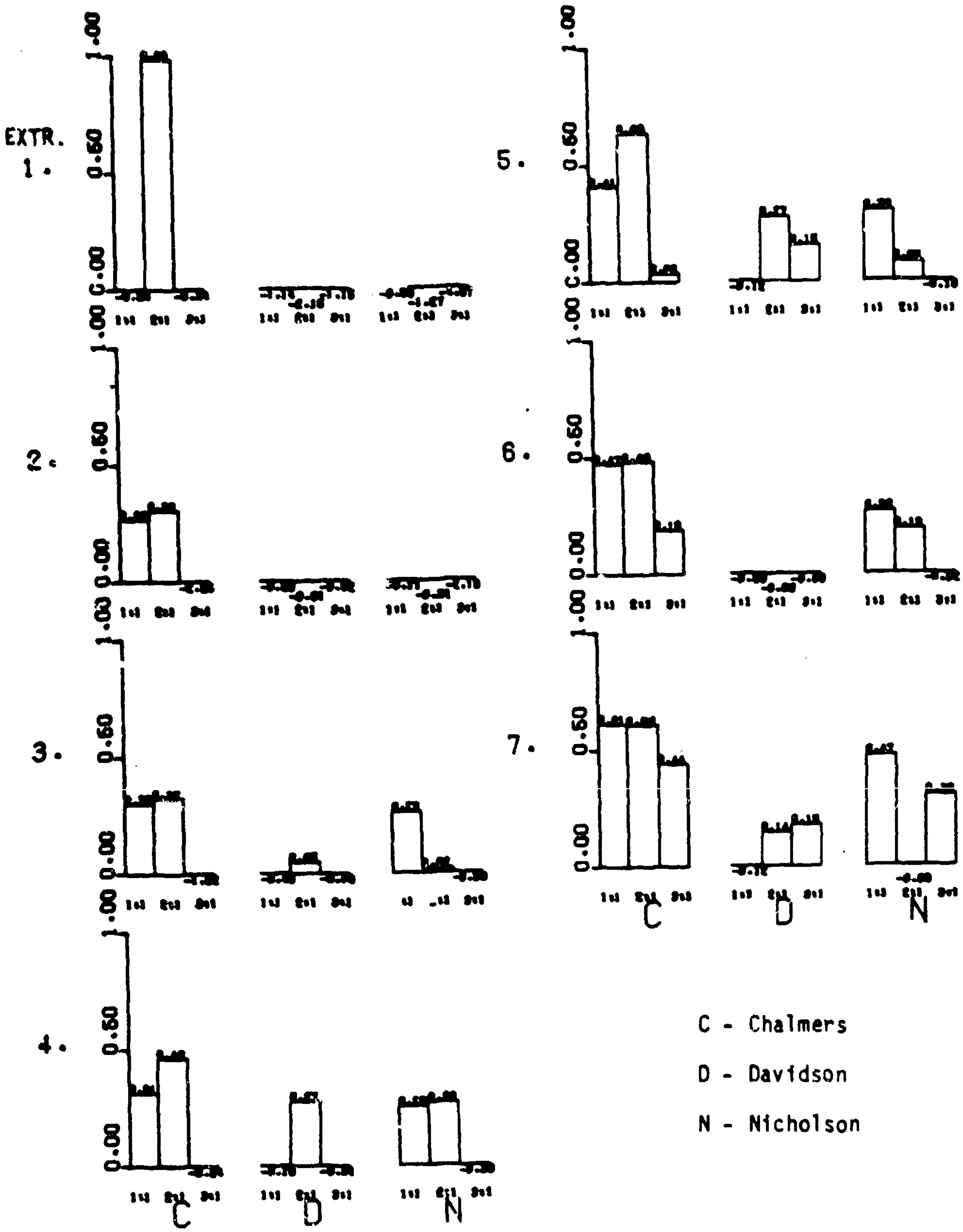

FIGURE 174. COMPARING FRACTION LEAD RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 92. LEAD FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UC/ML	AMT.PENETR. UC/G	AMT.RETD. THIS EXT. UC/G	CUM.TOT. CHALLG. UC/G	CUM.TOT. RETD. UC/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.94	9.89										
	I	6.38	12.76	-2.87	9.89	-2.87	-.29	-.29	1.29	7.49	82.40	-.23	-12.69
	II	.10	.20	12.56	12.76	12.56	.98	.98	.02	555.32	89.90	62.82	89.09
	III	31.36	62.72	-62.52	.20	-62.52	-312.58	-312.58	314.	.57	29.84	-1.00	-44.91
	I+II			4.04	4.94	4.84	.98	.98	.02	2010.45	89.97	48.45	88.82
	I+II+III			-17.61	3.30	-17.61	-5.34	-5.34	6.34	13.29	85.70	-.84	-40.11
2	W	5.05	17.56										
	I	2.49	7.47	10.10	27.45	7.22	.57	.26	.43	14.16	85.96	.97	44.04
	II	6.33	18.99	-11.52	20.23	1.04	-1.54	.05	2.54	5.24	79.20	.05	3.13
	III	9.24	27.71	-8.71	19.19	-71.23	-.46	-3.71	1.46	.98	44.55	-2.57	-68.75
	I+II			-.71	13.73	4.13	-.08	.30	1.08	21.10	87.30	.43	23.50
	I+II+III			-3.38	9.15	-20.99	-.58	-2.29	1.58	29.72	88.07	-2.27	-66.25
3	W	5.68	34.09										
	I	3.82	22.94	11.15	61.54	18.37	.33	.30	.67	5.09	78.90	.80	38.69
	II	3.77	22.61	.33	43.17	1.37	.01	.03	.99	4.42	77.25	.06	3.47
	III	10.80	64.78	-42.17	41.80	-113.40	-1.07	-2.71	2.07	-.23	-12.95	-1.75	-60.26
	I+II			5.74	30.77	9.07	.34	.32	.66	18.30	86.87	.87	41.13
	I+II+III			-10.23	20.51	-31.22	-.90	-1.52	1.90	12.24	85.3	-1.45	-55.33
4	W	4.04	58.05										
	I	3.26	39.18	18.87	119.5[illegible]	37.24	.33	.31	.67	3.46	73.90	.95	4[illegible].5[illegible]
	II	1.90	22.85	16.33	82.35	17.70	.42	.21	.58	5.09	78.88	.77	37.77
	III	2.37	28.48	-5.63	64.64	-119.83	-.25	-1.84	1.25	-.72	-35.79	-4.18	-76.55
	I+II			17.66	59.79	27.47	.61	.46	.39	19.65	87.09	2.41	67.42
	I+II+III			9.86	39.96	-21.36	.51	-.54	.49	28.88	88.02	-2.25	-66.04
5	W	3.33	79.93										
	I	1.51	36.17	43.76	1[illegible]9.52	81.01	.55	.41	.45	[illegible].96	78.61	2.24	65.94
	II	.37	8.79	27.38	118.52	45.[illegible]8	.76	.38	.24	16.33	86.50	5.13	78.96
	III	.39	9.26	-.46	73.44	-119.49	-.05	-1.63	1.05	-2.27	-66.21	-12.91	-85.57
	I+II			35.57	99.76	63.04	.89	.63	.11	59.15	89.03	14.34	86.01
	I+II+III			23.56	66.51	2.20	.88	.03	.12	96.48	89.41	.71	35.45
6	W	.90	43.01										
	I	.21	9.87	33.13	242.53	114.14	.77	.47	.23	21.54	87.34	11.56	85.06
	II	1.11	53.07	-43.20	128.39	1.88	-4.38	.01	5.38	1.89	62.14	.04	2.03
	III	<.10	<4.00	40.27	126.51	-71.22	.91	-.56	.09	5.68	80.02	-14.84	-86.14
	I+II			-5.03	121.26	58.01	-.23	.48	1.23	9.61	84.06	2.19	65.42
	I+II+III			12.74	80.84	14.93	.89	.18	.11	194.02	89.70	9.33	83.88
7	W	1.31	125.66										
	I	.17	16.03	109.63	368.18	223.76	.87	.61	.13	20.10	87.15	13.96	85.90
	II	.21	19.75	-3.72	144.42	-1.83	-.23	-.01	1.23	4.90	78.45	-.09	-5.30
	III	<.10	<9.60	10.15	146.25	-61.08	.51	-.42	.49	3.90	75.61	-6.36	-81.07
	I+II			52.95	184.09	110.97	.84	.60	.16	31.19	88.15	11.24	84.92
	I+II+III			38.69	122.73	53.62	.92	.44	.08	109.10	89.47	16.76	86.58

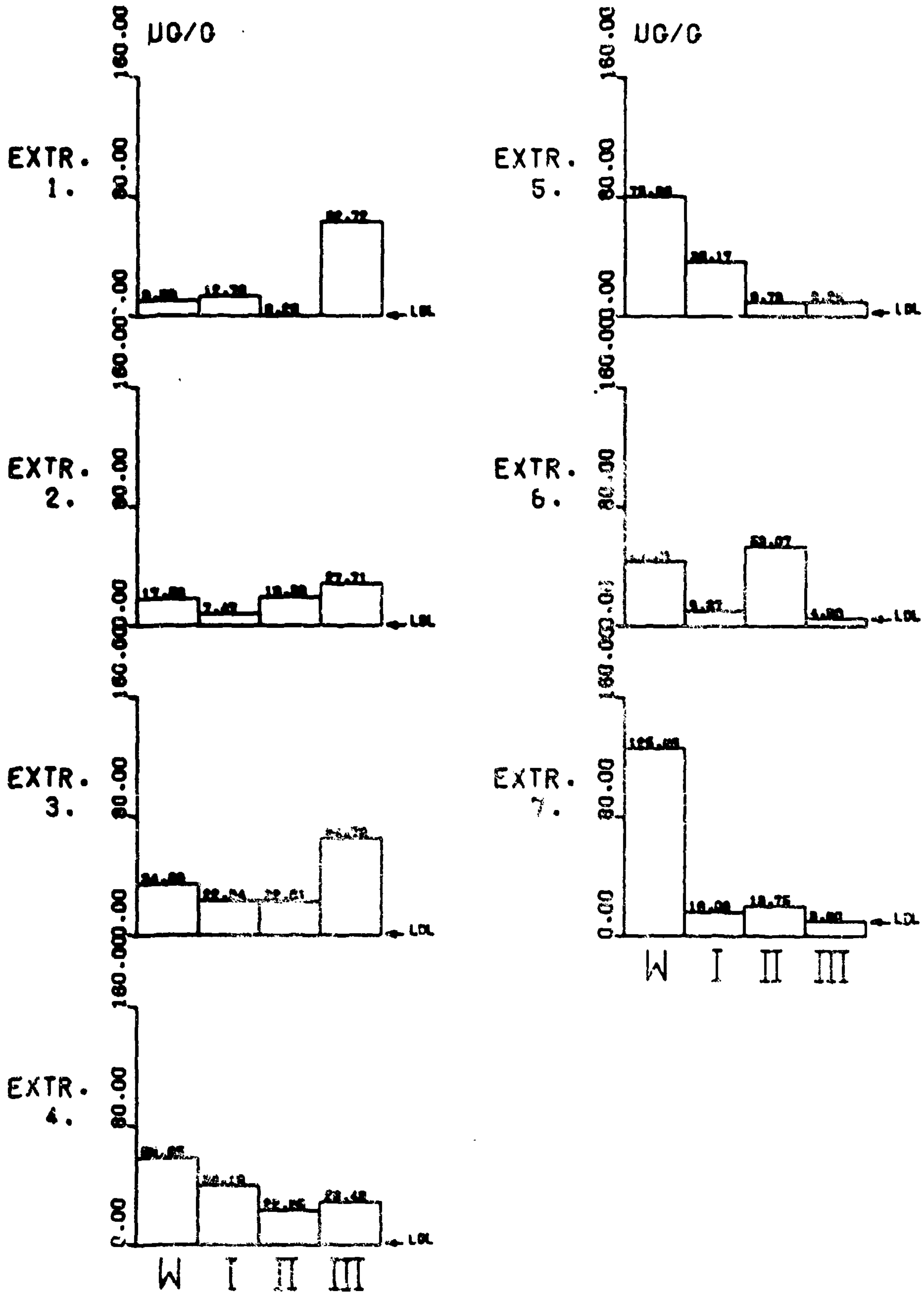

FIGURE 175. WEIGHT OF LEAD FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 93. LEAD FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.74	9.89										
	I	10.58	21.16	-11.27	9.89	-11.27	-1.14	-1.14	2.14	6.74	81.57	-.53	-28.05
	II	15.58	31.15	-9.99	21.16	-9.99	-.47	-.47	1.47	4.62	77.79	-.32	-17.78
	III	10.62	21.25	9.90	31.15	9.90	.32	.32	.68	7.71	82.61	.47	24.99
	I+II			-10.63	4.94	-10.63	-2.15	-2.15	3.15	19.09	87.00	-.68	-34.32
	I+II+III			-3.79	3.30	-3.79	-1.15	-1.15	2.15	64.69	89.11	-.53	-28.13
2	W	5.89	17.56										
	I	3.89	11.68	5.89	27.45	-5.39	.34	-.20	.66	12.73	85.51	-.46	-24.77
	II	4.32	12.96	-1.28	32.04	-11.28	-.11	-.34	1.11	11.01	84.81	-.87	-41.02
	III	9.58	28.80	-15.84	44.11	-5.93	-1.22	-.13	2.22	5.14	78.99	-.21	-11.64
	I+II			2.38	13.73	-8.33	.26	-.61	.74	46.24	88.76	-1.29	-52.12
	I+II+III			-3.74	9.15	-7.53	-.64	-.82	1.64	47.35	88.79	-.78	-38.12
3	W	5.60	34.89										
	I	9.66	57.99	-23.90	61.54	-25.29	-.70	-.40	1.70	2.15	65.06	-.51	-26.88
	II	2.44	14.64	43.35	90.83	32.87	.75	.35	.25	12.71	85.50	2.19	65.46
	III	2.85	17.09	-2.45	58.76	-8.38	-.17	-.14	1.17	8.52	83.31	-.49	-26.12
	I+II			9.72	30.77	1.39	.57	.05	.43	42.26	88.64	.19	10.77
	I+II+III			5.67	20.51	-1.87	.50	-.09	.50	95.76	89.29	-.33	-18.13
4	W	4.84	58.05										
	I	4.82	60.24	9.81	119.59	-19.48	.17	-.16	.83	2.79	70.27	-.40	-21.99
	II	2.36	28.34	17.96	139.07	51.96	.41	.37	.59	7.27	82.17	1.83	61.40
	III	4.47	53.69	-25.35	87.09	-33.73	-.89	-.39	1.89	2.24	65.94	-.63	-32.14
	I+II			14.86	59.79	16.25	.51	.27	.49	22.38	87.50	1.15	48.91
	I+II+III			1.45	39.86	-.41	.08	-.01	.92	25.79	87.78	-.02	-1.32
5	W	3.33	79.93										
	I	3.52	84.36	-4.43	199.52	-23.91	-.06	-.12	1.06	1.54	57.04	-.28	-15.82
	II	2.42	58.05	26.31	223.43	78.28	.31	.35	.69	4.00	75.97	1.35	53.44
	III	2.01	48.17	9.88	145.15	-23.95	.17	-.16	.83	2.70	69.69	-.50	-26.34
	I+II			10.9[illegible]	99.76	27.19	.27	.27	.73	11.55	85.05	.94	43.13
	I+II+III			10.59	66.51	18.18	.40	.13	.60	29.41	83.05	.63	32.37
6	W	.93	43.81										
	I	2.93	146.40	-97.47	242.53	-121.38	-2.27	-.50	3.27	.23	13.07	-.86	-40.83
	II	2.32	111.25	29.23	363.91	107.52	.21	.30	.79	2.35	66.96	.97	44.02
	III	1.92	91.74	19.50	256.39	-4.35	.18	-.02	.82	1.63	58.49	-.05	-2.71
	I+II			-54.12	121.26	-6.93	-1.59	-.06	2.59	5.41	79.53	-.12	-7.10
	I+II+III			-16.25	80.84	-6.07	-1.13	-.08	2.13	14.91	86.16	-.20	-11.23
7	W	1.31	125.66										
	I	.58	40.88	77.50	368.18	-43.80	.62	-.12	.38	2.29	66.43	-.91	-42.34
	II	.62	59.54	-11.46	411.99	96.06	-.24	.23	1.24	4.20	76.61	1.61	58.21
	III	45	42.93	16.68	315.93	12.26	.29	.04	.72	3.87	75.52	.29	15.94
	I+II			33.06	184.37	26.13	.53	.14	.47	11.22	84.91	.88	41.27
	I+II+III			27.57	122.73	21.51	.66	.18	.34	33.79	88.30	1.50	56.36

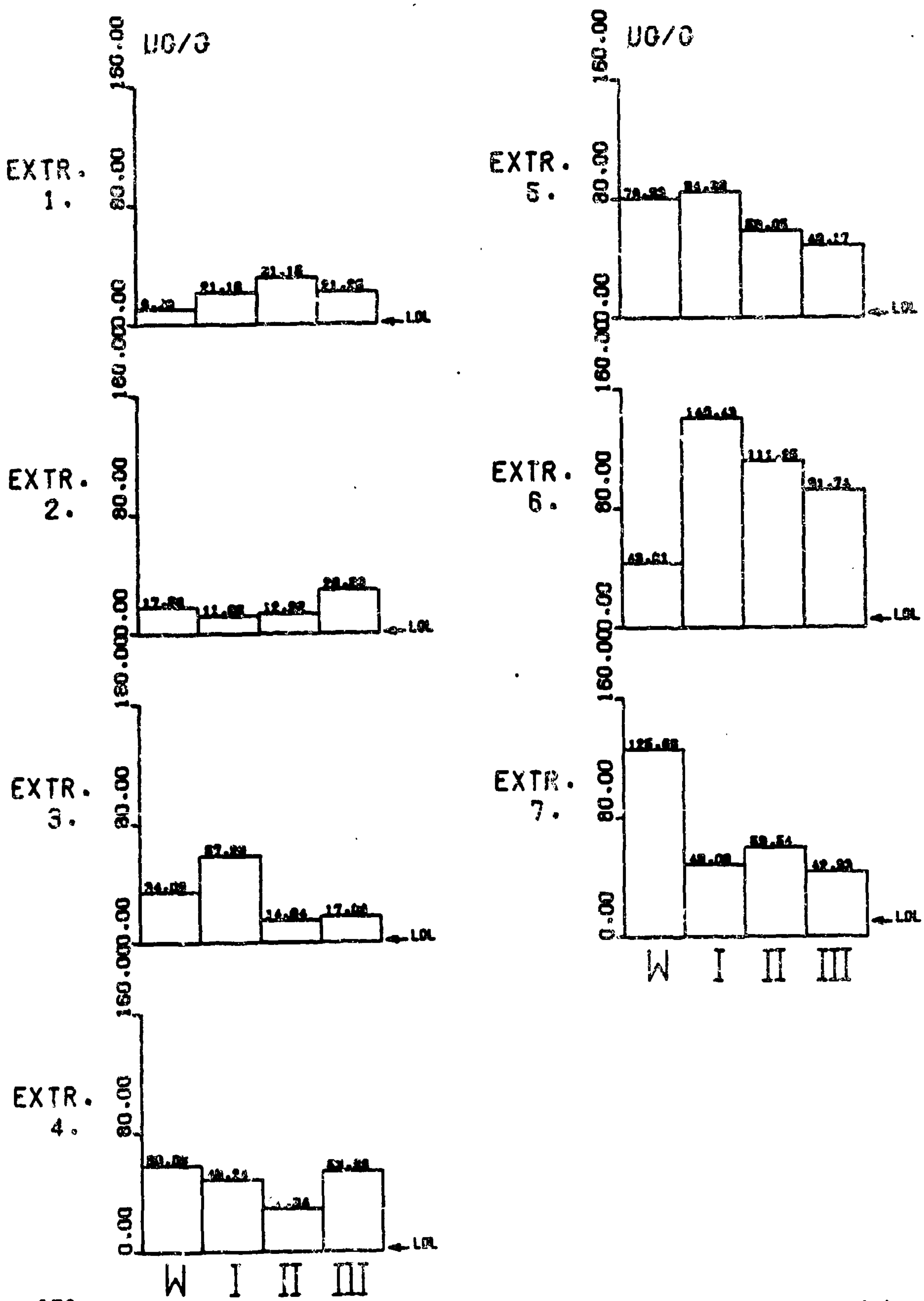

FIGURE 176. WEIGHT OF LEAD FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

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TABLE 94. LEAD FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.94	7.89										
	I	9.21	10.41	-0.52	9.89	-0.52	-.06	-.04	1.06	4.95	78.57	-.46	-24.84
	II	11.22	22.44	-4.03	10.41	-4.03	-.22	-.22	1.22	4.26	76.79	-.10	-10.18
	III	27.56	55.13	-32.69	22.44	-32.69	-1.46	-1.46	2.46	1.21	50.52	-.59	-30.67
	I+II			-6.27	4.94	-6.27	-1.27	-1.27	2.27	17.20	86.67	-.56	-29.22
	I+II+III			-15.08	3.30	-15.08	-4.57	-4.57	5.57	15.44	86.29	-.82	-39.37
2	W	5.85	17.56										
	I	3.99	11.96	5.60	27.45	-2.92	.32	-.11	.68	8.08	82.95	-.24	-13.71
	II	4.54	13.62	-1.66	30.37	-5.69	-.14	-.19	1.14	6.90	81.75	-.42	-22.67
	III	10.78	32.35	-18.73	36.06	-51.42	-1.38	-1.43	2.38	1.49	56.12	-1.59	-57.82
	I+II			1.97	13.73	-4.30	.22	-.31	.78	28.62	88.00	-.63	-32.29
	I+II+III			-4.93	9.15	-20.01	-.84	-2.19	1.84	25.85	87.78	-1.86	-61.68
3	W	5.60	34.09										
	I	2.55	15.32	18.76	61.54	15.85	.55	.26	.45	7.53	82.44	1.03	45.96
	II	4.09	24.52	-9.20	45.69	-14.89	-.60	-.33	1.60	3.45	73.85	-.61	-31.26
	III	4.77	28.66	-4.07	60.58	-55.50	-.17	-.92	1.17	1.54	57.04	-1.94	-62.74
	I+II			4.78	30.77	.40	.28	.02	.72	16.28	86.49	.04	2.24
	I+II+III			1.83	20.51	-18.18	.16	-.09	.84	29.44	88.05	-1.91	-62.33
4	W	4.04	58.05										
	I	3.68	44.21	13.84	119.59	29.68	.24	.25	.76	2.92	71.12	.67	33.88
	II	2.28	27.34	16.88	89.91	1.99	.38	.02	.62	3.72	74.94	.07	4.11
	III	4.12	49.58	-22.16	87.92	-77.66	-.81	-.88	1.81	.44	23.91	-1.57	-57.49
	I+II			15.36	59.79	15.84	.53	.26	.47	15.73	86.36	1.16	49.20
	I+II+III			2.85	39.86	-15.33	.15	-.38	.85	17.18	86.67	-.93	-42.89
5	W	3.32	79.93										
	I	2.11	58.54	29.39	199.52	59.08	.37	.30	.63	3.14	72.33	1.17	49.45
	II	4.01	96.35	-45.81	140.45	-43.82	-.91	-.31	1.91	.58	30.07	-.45	-24.46
	III	2.73	65.54	30.80	184.26	-46.86	.32	-.25	.68	.80	38.82	-.71	-35.56
	I+II			-8.21	99.76	7.63	-.21	.08	1.21	4.29	76.89	.16	9.00
	I+II+III			4.80	66.51	-10.53	.18	-.16	.82	13.19	85.67	-.48	-25.74
6	W	.70	43.01										
	I	.80	38.55	4.46	242.53	63.54	.10	.26	.90	4.23	76.71	1.65	58.76
	II	.27	13.18	25.37	178.99	-18.45	.66	-.10	.34	6.16	80.78	-1.40	-54.46
	III	.36	17.14	-3.96	197.44	-50.82	-.30	-.26	1.30	2.85	70.64	-2.96	-71.36
	I+II			14.91	121.26	22.54	.69	.19	.31	33.65	88.30	3.42	73.71
	I+II+III			8.62	80.84	-1.91	.60	-.02	.40	51.96	88.90	-.33	-18.49
7	W	1.31	125.66										
	I	.17	15.94	109.71	368.18	173.25	.87	.47	.13	17.11	86.66	10.87	84.74
	II	2.11	203.03	-187.09	194.94	-205.54	-11.73	-1.05	12.73	-.52	-27.55	-1.01	-45.35
	III	.10	9.60	193.43	400.47	142.61	.95	.36	.05	25.23	87.73	14.86	86.15
	I+II			-38.69	184.09	-16.14	-.62	-.09	1.62	1.80	60.99	-.16	-9.04
	I+II+III			38.69	122.73	36.77	.92	.30	.08	104.87	89.45	11.49	85.03

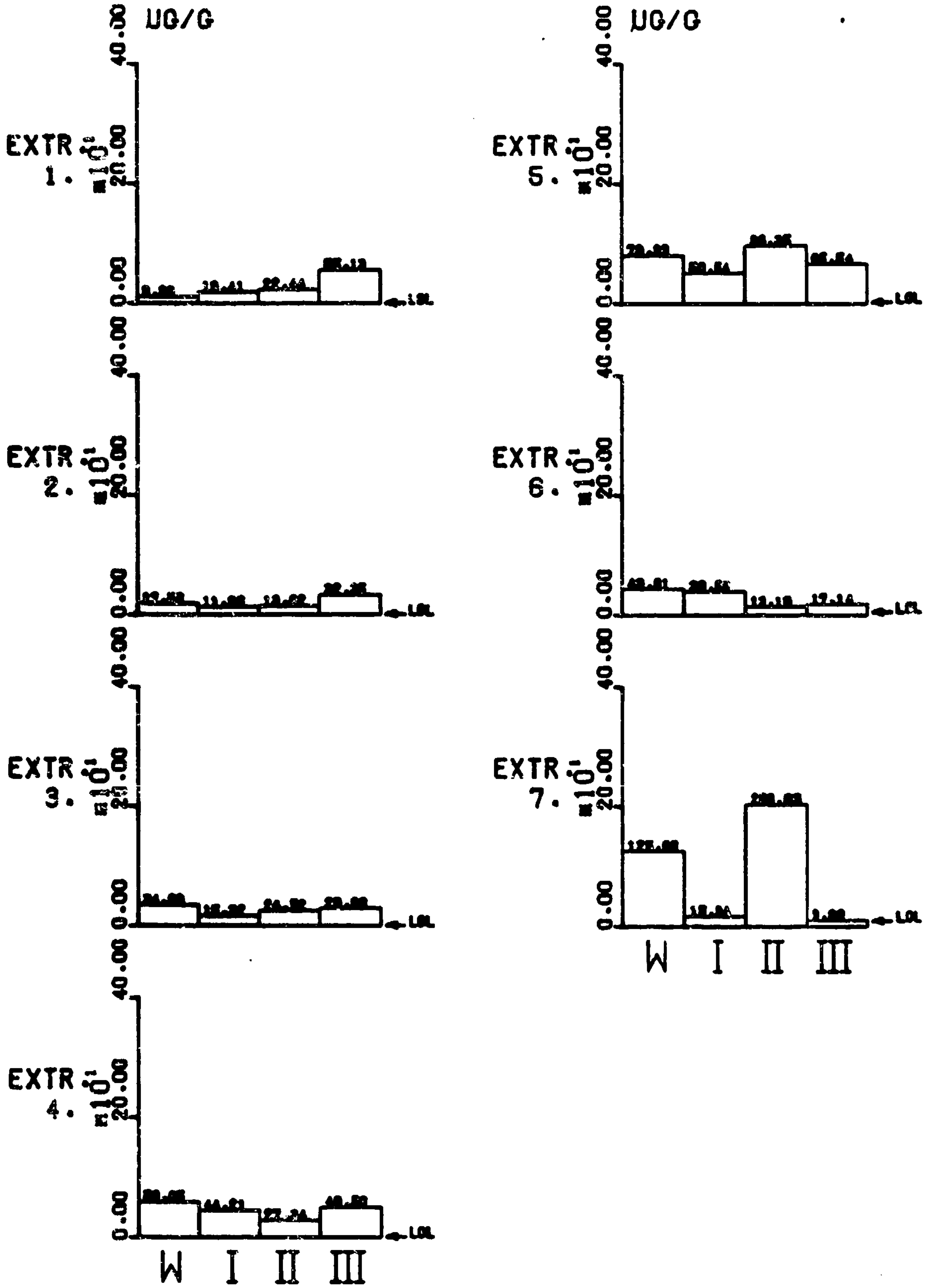

FIGURE 177. WEIGHT OF LEAD FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

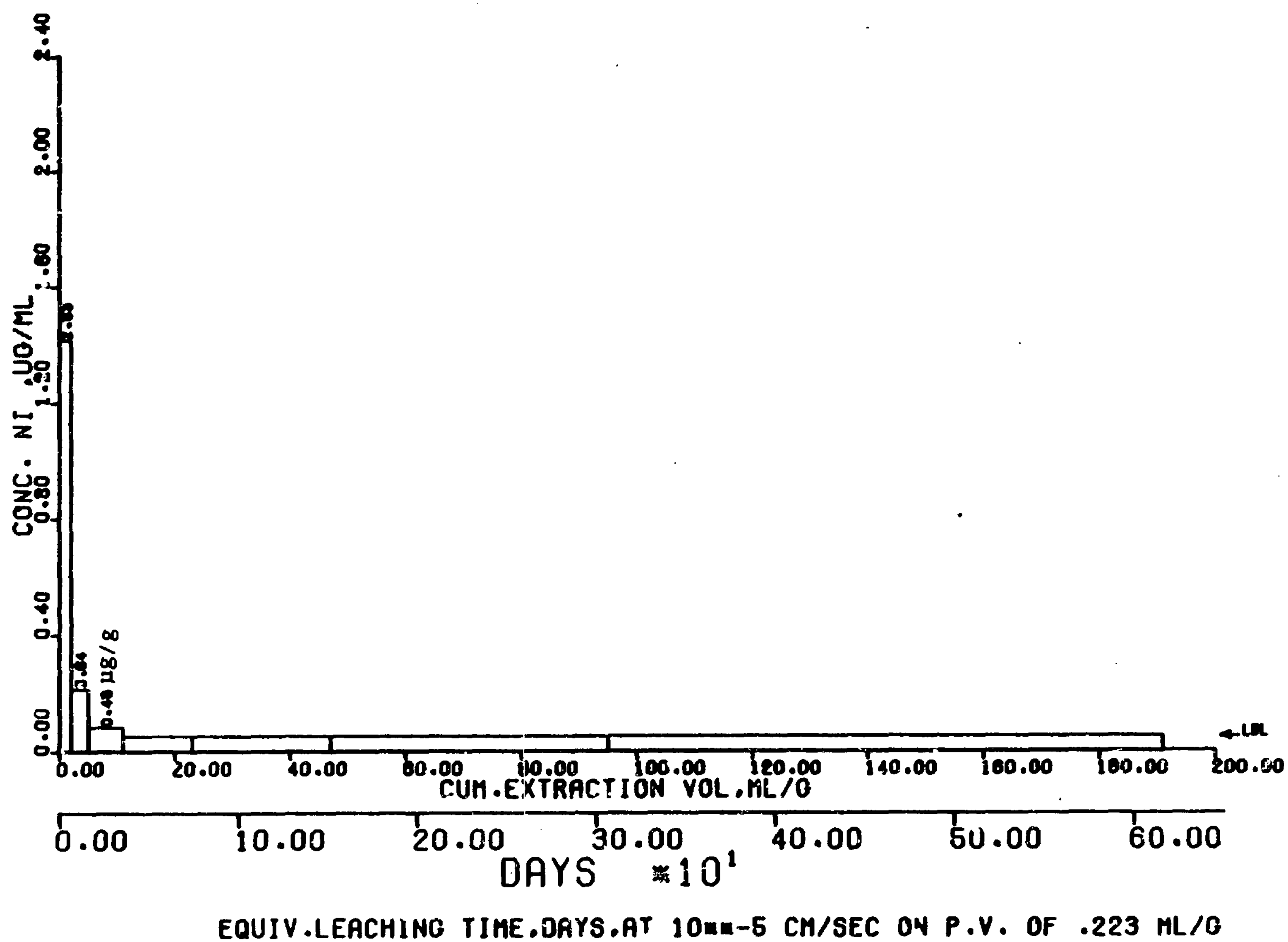

FIGURE 178. EXTRACTION OF NICKEL FROM OIL RE-REFINING WASTE (A).

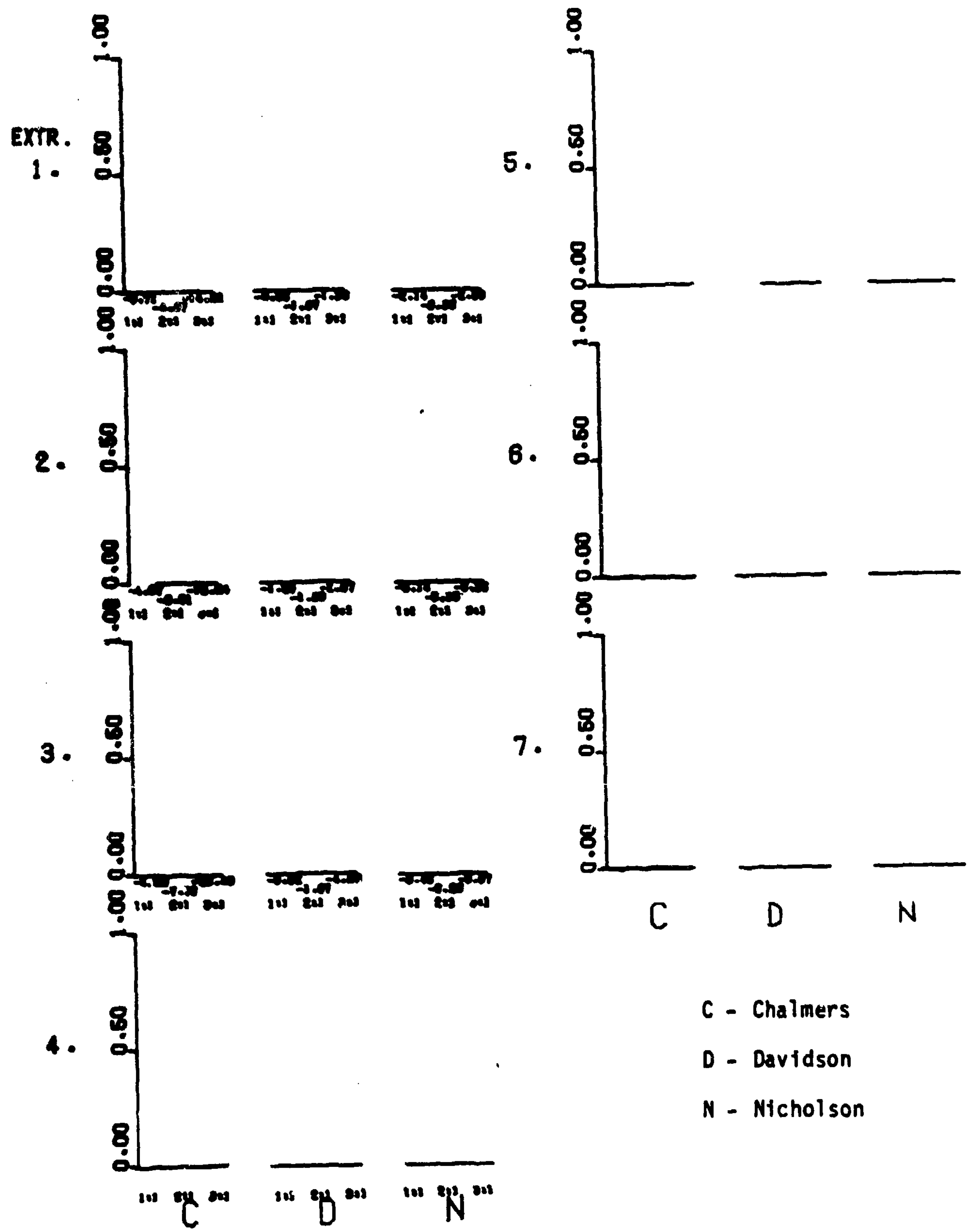

FIGURE 179. COMPARING FRACTION NICKEL RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 95. NICKEL FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	1.41	2.83										
	I	6.67	13.33	-10.53	2.83	-10.50	-3.71	-3.71	4.71	1.06	46.60	-.79	-38.23
	II	7.17	14.34	-1.01	13.33	-1.01	-.08	-.08	1.08	1.64	58.70	-.07	-4.03
	III	21.51	43.03	-28.68	14.34	-28.68	-2.00	-2.00	3.00	-.09	-5.02	-.67	-33.69
	I+II			-5.76	1.41	-5.76	-4.07	-4.07	5.07	6.06	80.63	-.80	-38.76
	I+II+III			-13.40	.94	-13.40	-14.21	-14.21	15.21	4.21	76.64	-.93	-43.05
2	W	.21	.64										
	I	1.41	4.24	-3.61	3.46	-14.11	-5.67	-4.07	6.67	2.47	67.98	-3.33	-73.27
	II	4.24	12.73	-0.48	17.57	-9.49	-2.00	-.54	3.00	1.19	49.09	-.75	-36.72
	III	7.88	23.63	-10.91	27.07	-39.59	-.86	-1.46	1.86	-.63	-32.39	-1.60	-59.17
	I+II			-6.04	1.73	-11.80	-19.00	-6.81	20.00	5.88	80.34	-1.85	-61.67
	I+II+III			-7.67	1.15	-21.07	-36.14	-18.24	37.14	6.69	81.50	-2.67	-69.50
3	W	.08	.48										
	I	.54	3.21	-2.73	3.95	-16.84	-5.63	-4.26	6.63	2.42	67.52	-5.24	-79.20
	II	1.21	7.27	-4.06	20.79	-13.55	-1.26	-.65	2.26	1.52	56.64	-1.86	-61.79
	III	3.03	18.18	-10.91	34.34	-50.50	-1.50	-1.47	2.50	-1.42	-54.93	-2.78	-70.20
	I+II			-3.39	1.97	-15.20	-14.00	-7.70	15.00	9.35	83.90	-4.18	-76.54
	I+II+III			-5.90	1.32	-26.96	-36.50	-20.40	37.50	7.73	82.63	-4.45	-77.33
4	W	<.05	<.61										
	I	<.05	<.61										
	II	.13	1.58										
	III	.58	6.91										
	I+II												
	I+II+III												
5	W	<.05	<1.21										
	I	<.05	<1.21										
	II	<.05	<1.21										
	III	<.05	<1.21										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

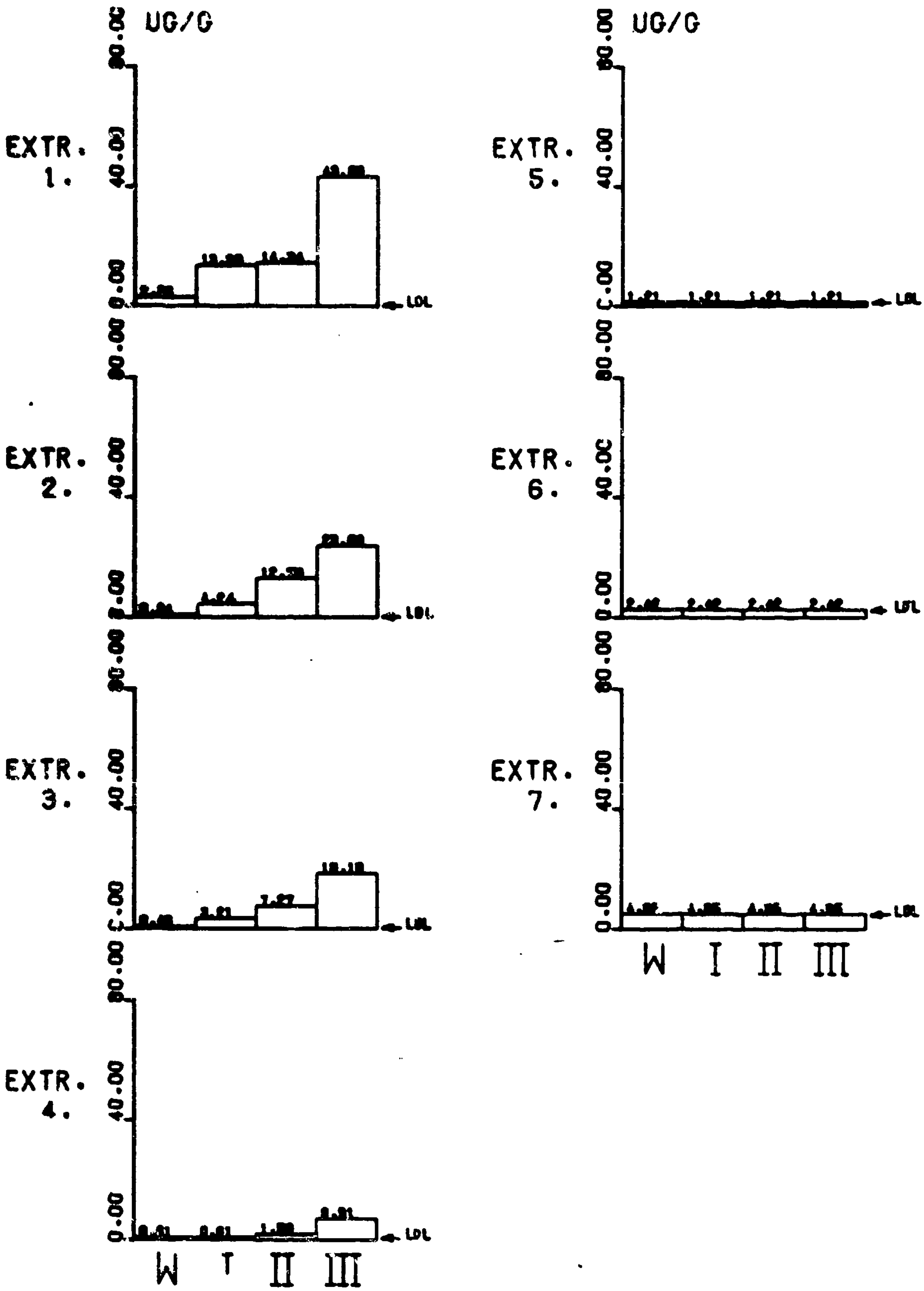

FIGURE 180. WEIGHT OF NICKEL FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 96. NICKEL FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	1.41	2.83										
	I	2.63	5.25	-2.42	2.83	-2.42	-.86	-.86	1.86	2.53	68.42	-.46	-24.70
	II	2.93	5.86	-.61	5.25	-.61	-.12	-.12	1.12	2.58	68.79	-.10	-5.91
	III	3.33	6.67	-.81	5.86	-.81	-.14	-.14	1.14	2.23	65.89	-.12	-6.91
	I+II			-1.51	1.41	-1.51	-1.07	-1.07	2.07	10.20	84.40	-.52	-27.35
	I+II+III			-1.28	.94	-1.28	-1.36	-1.36	2.36	20.62	87.22	-.58	-29.93
2	W	.21	.64										
	I	.90	2.70	-2.06	3.46	-4.48	-3.24	-1.29	4.24	4.16	76.48	-1.66	-58.98
	II	.35	1.06	1.64	7.95	1.03	.61	.13	.39	15.78	86.37	.97	44.17
	III	2.02	6.06	-5.00	6.92	-5.81	-4.71	-.84	5.71	1.63	58.51	-.96	-43.78
	I+II			-.21	1.73	-1.73	-.67	-1.00	1.67	55.96	88.98	-3.26	-72.93
	I+II+III			-1.81	1.15	-3.09	-6.52	-2.67	9.52	21.79	87.37	-1.53	-56.80
3	W	.08	.48										
	I	1.72	10.30	-9.82	3.95	-14.30	-20.25	-3.62	21.25	.14	7.73	-1.39	-54.27
	II	.61	3.64	6.67	10.25	7.70	.65	.42	.35	6.43	81.17	2.12	64.71
	III	1.21	7.27	-3.64	10.55	-9.44	-1.00	-.89	2.00	.86	40.71	-1.30	-52.40
	I+II			-1.58	1.97	-3.30	-6.50	-1.67	7.50	15.46	86.30	-1.82	-61.17
	I+II+III			-2.26	1.32	-5.35	-14.00	-4.06	15.00	17.22	86.68	-2.21	-65.62
4	W	<.05	<.61										
	I	<.05	<.61										
	II	.13	1.58										
	III	.25	3.03										
	I+II												
	I+II+III												
5	W	<.05	<1.21										
	I	<.05	<1.21										
	II	<.05	<1.21										
	III	<.05	<1.21										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

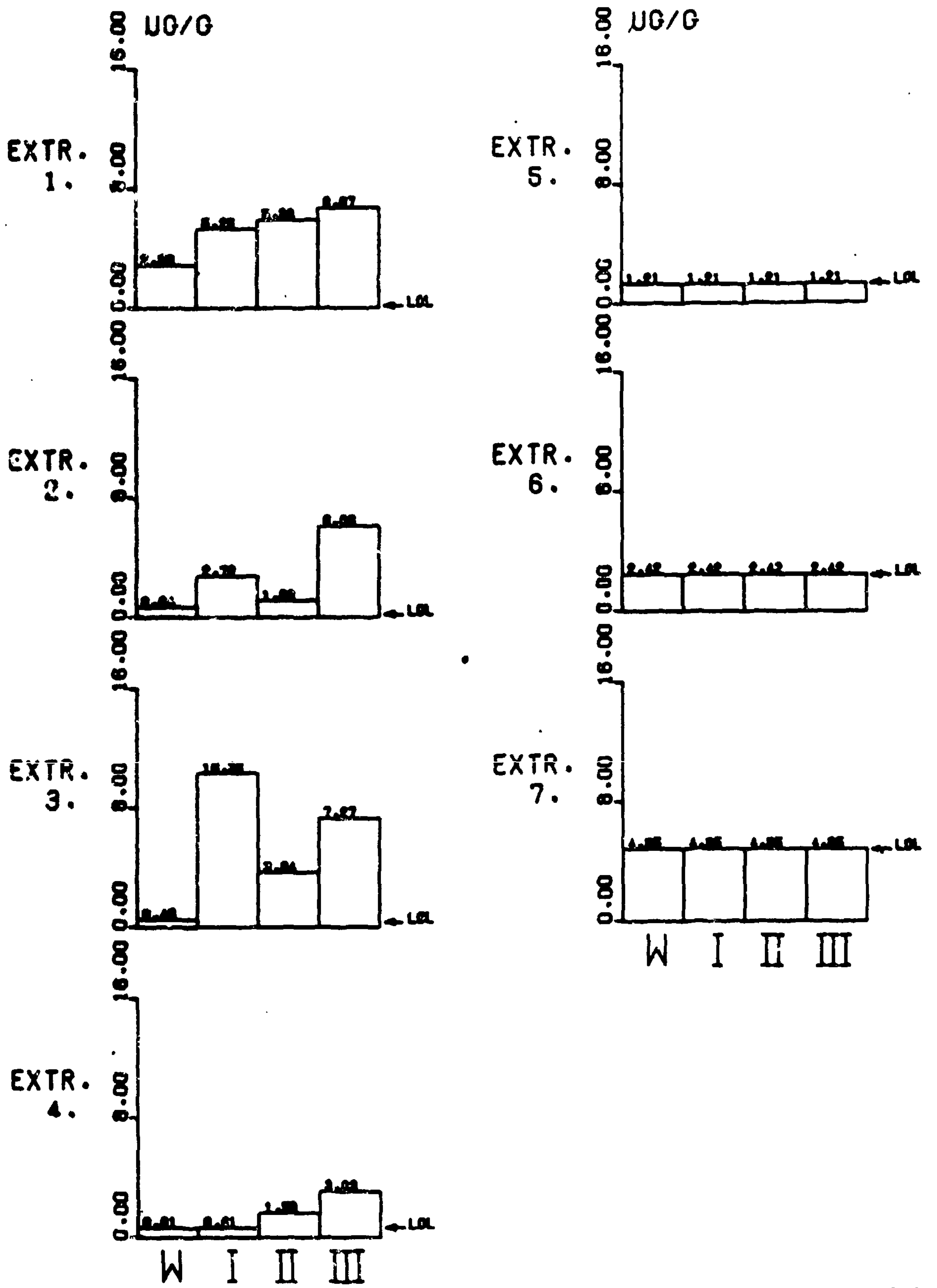

FIGURE 181. WEIGHT OF NICKEL FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 97. NICKEL FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	U	1.41	2.83										
	I	4.44	8.89	-6.06	2.83	-6.06	-2.14	-2.14	3.14	2.66	64.14	-.68	-34.29
	II	6.16	12.32	-3.43	8.89	-3.43	-.39	-.39	1.39	1.70	59.56	-.20	-15.57
	III	4.24	8.48	3.04	12.32	3.04	.31	.31	.69	3.33	73.28	.45	24.34
	I+II			-4.75	1.41	-4.75	-3.36	-3.36	4.36	7.15	82.04	-.77	-37.61
	I+II+III			-1.89	.94	-1.89	-2.00	-2.00	3.00	25.22	87.73	-.67	-33.69
2	U	.21	.64										
	I	1.82	5.45	-4.82	3.46	-10.86	-7.57	-3.14	8.57	2.40	68.03	-1.99	-63.37
	II	3.23	9.70	-4.24	14.34	-7.60	-.70	-.54	1.70	1.72	59.90	-.79	-38.37
	III	5.66	16.97	-7.27	22.02	-3.43	-.75	-.16	1.75	1.24	51.02	-.20	-11.44
	I+II			-4.53	1.73	-9.20	-14.24	-5.36	15.24	8.15	83.01	-1.91	-62.41
	I+II+III			-5.44	1.15	-7.33	-25.67	-6.35	26.67	11.65	85.09	-1.30	-52.34
3	U	.08	.48										
	I	.55	3.27	-2.79	3.95	-13.67	-5.75	-3.46	6.75	3.28	73.05	-4.18	-76.53
	II	1.11	6.67	-3.39	17.61	-11.07	-1.04	-.63	2.04	2.00	63.43	-1.66	-58.94
	III	2.12	12.73	-6.06	28.68	-9.49	-.91	-.33	1.91	1.17	49.51	-.75	-36.72
	I+II			-3.09	1.97	-12.37	-12.75	-5.26	13.75	18.93	84.77	-3.71	-74.92
	I+II+III			-4.03	1.32	-11.41	-25.25	-8.67	24.25	14.57	86.07	-2.69	-69.61
4	U	<.05	<.61										
	I	<.05	<.61										
	II	.20	2.42										
	III	.64	7.64										
	I+II												
	I+II+III												
5	U	<.05	<1.21										
	I	<.05	<1.21										
	II	<.05	<1.21										
	III	<.07	<1.70										
	I+II												
	I+II+III												
6	U	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	U	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

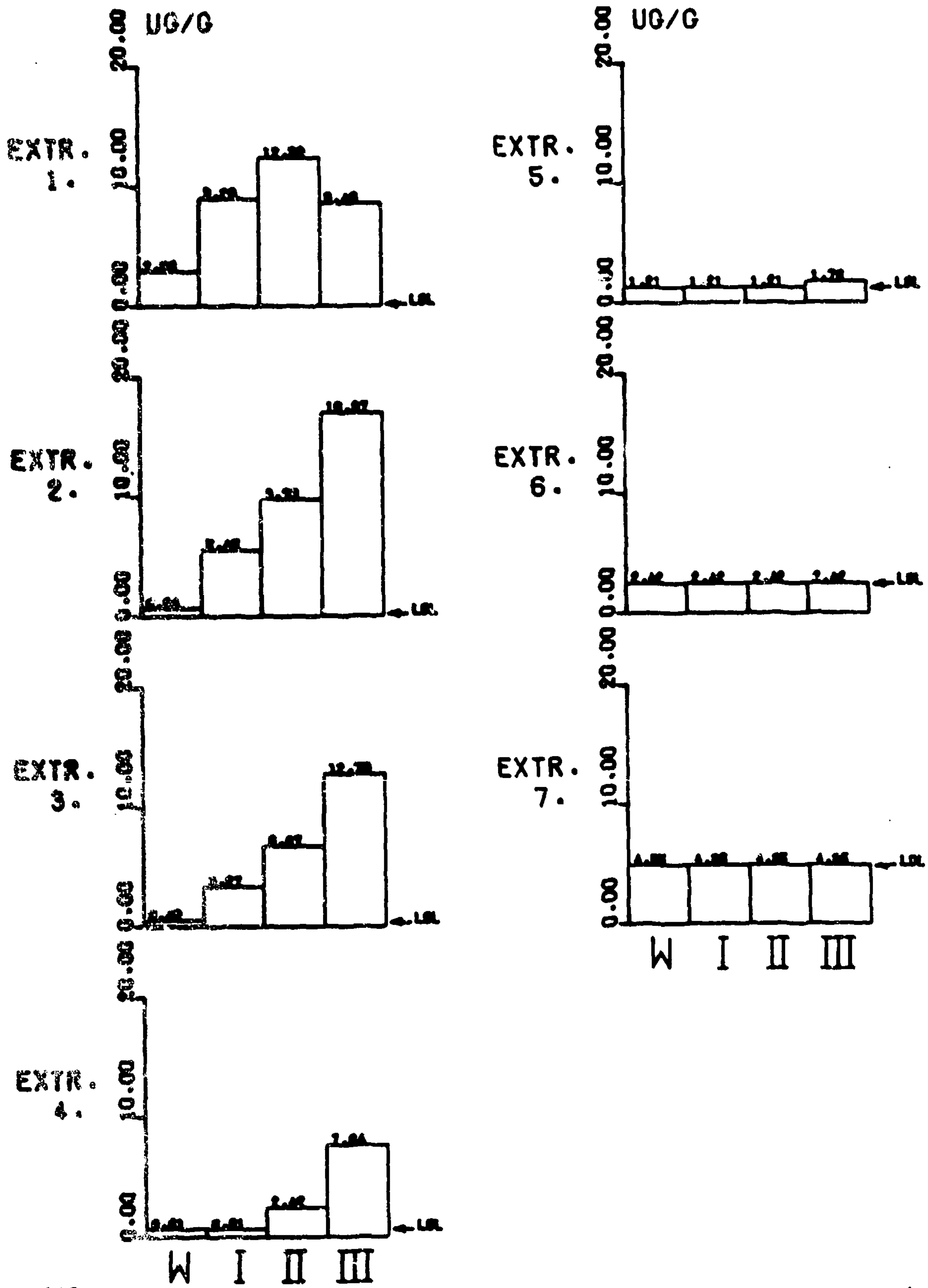

FIGURE 182. WEIGHT OF NICKEL FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

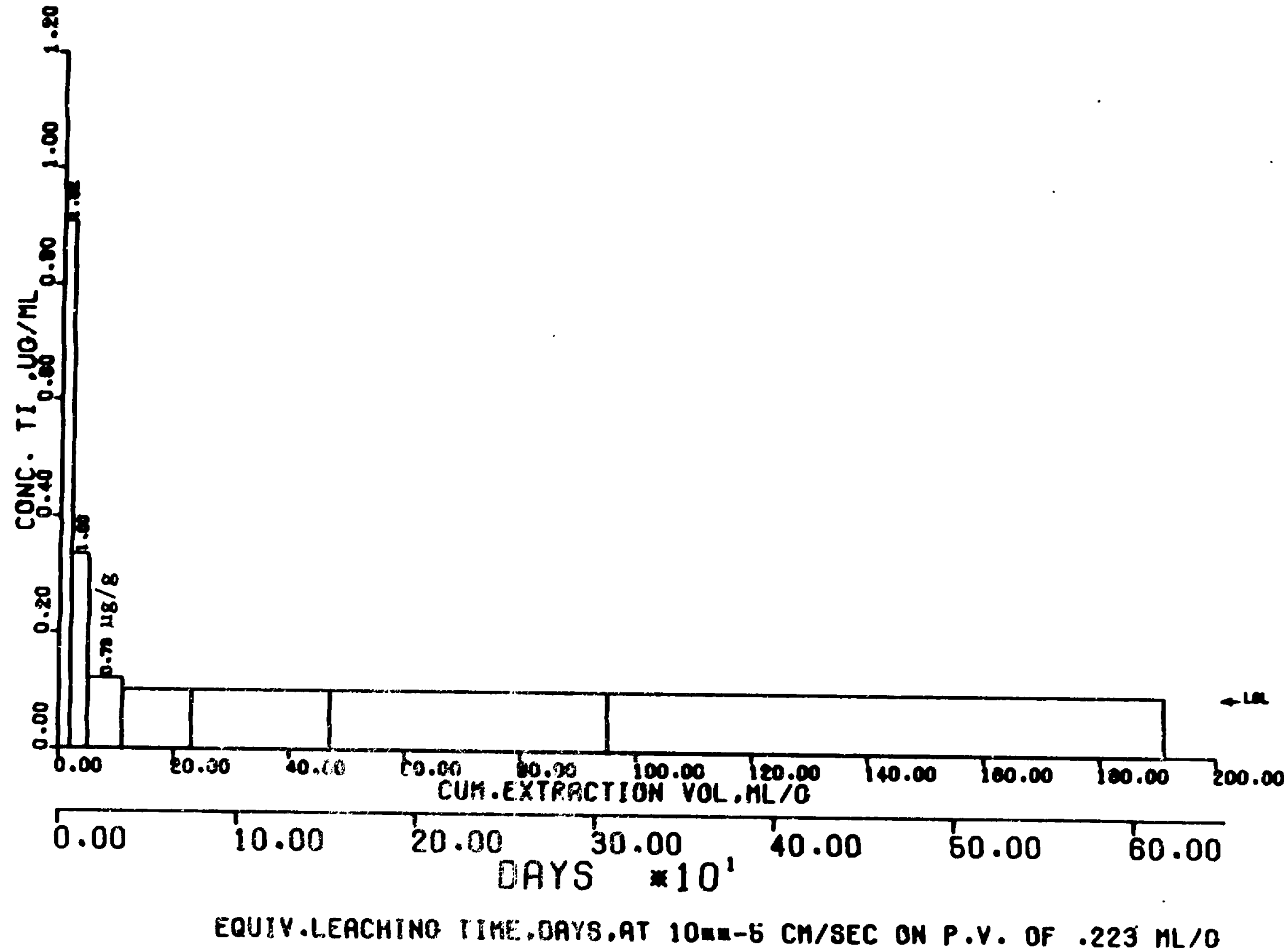

FIGURE 183. EXTRACTION OF TITANIUM FROM OIL RE-REFINING WASTE (A).

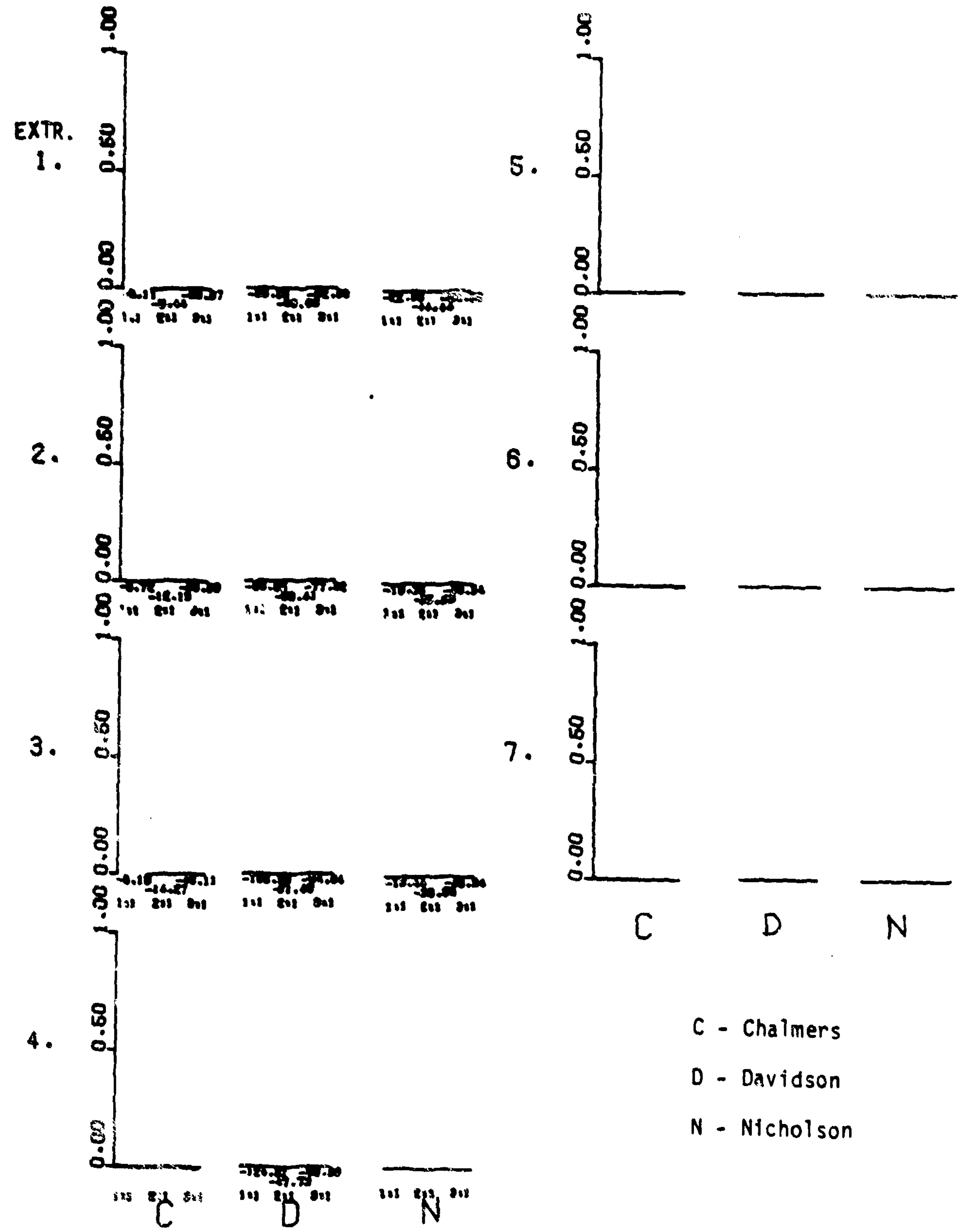

FIGURE 184. COMPARING FRACTION TITANIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 9C. TITANIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

CORE NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.91	1.82										
	I	9.19	18.38	-16.56	1.82	-16.56	-9.11	-9.11	10.11	4.76	78.13	-.90	-42.02
	II	8.58	17.17	1.21	18.38	1.21	.07	.07	.93	6.13	80.73	.07	4.04
	III	28.78	57.57	-40.40	17.17	-40.40	-2.35	-2.35	3.35	1.10	47.85	-.70	-35.06
	I+II			-7.68	.91	-7.68	-8.44	-8.44	9.44	23.33	87.55	-.89	-41.68
	I+II+III			-18.58	.61	-18.58	-30.67	-30.67	31.67	15.29	86.26	-.97	-44.08
2	W	.33	1.00										
	I	3.94	11.82	-10.82	2.82	-27.38	-10.82	-9.72	11.82	6.48	81.23	-2.32	-66.66
	II	6.67	20.01	-8.18	30.22	-6.97	-.69	-.23	1.69	4.85	78.35	-.35	-19.21
	III	10.00	30.00	-10.00	37.17	-50.40	-.50	-1.36	1.50	1.79	60.77	-1.68	-59.24
	I+II			-9.50	1.41	-17.19	-19.88	-12.19	20.88	19.83	87.08	-1.72	-59.79
	I+II+III			-9.67	.94	-29.25	-29.88	-30.88	30.88	28.38	87.98	-2.83	-70.51
3	W	.12	.73										
	I	.98	5.88	-5.15	3.55	-32.53	-7.08	-9.18	8.08	12.16	85.30	-5.53	-79.76
	II	2.83	16.97	-11.09	36.08	-18.86	-1.89	-.50	2.89	5.06	78.83	-1.06	-46.78
	III	9.70	58.19	-41.21	54.14	-91.61	-2.43	-1.69	3.43	.21	12.03	-1.57	-57.58
	I+II			-8.12	1.77	-25.30	-22.33	-14.27	23.33	21.54	87.34	-2.98	-71.46
	I+II+III			-19.15	1.18	-47.40	-79.00	-40.11	80.00	13.64	85.81	-2.44	-67.75
4	W	<.10	<1.21										
	I	<.10	<1.21										
	II	.13	1.58										
	III	.92	11.03										
	I+II												
	I+II+III												
5	W	<.10	<2.42										
	I	<.10	<2.42										
	II	<.10	<2.42										
	III	.23	5.58										
	I+II												
	I+II+III												
6	W	<.10	<4.85										
	I	<.10	<4.85										
	II	<.10	<4.85										
	III	<.10	<4.85										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	<.10	<9.70										
	II	.11	10.67										
	III	<.10	<9.70										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

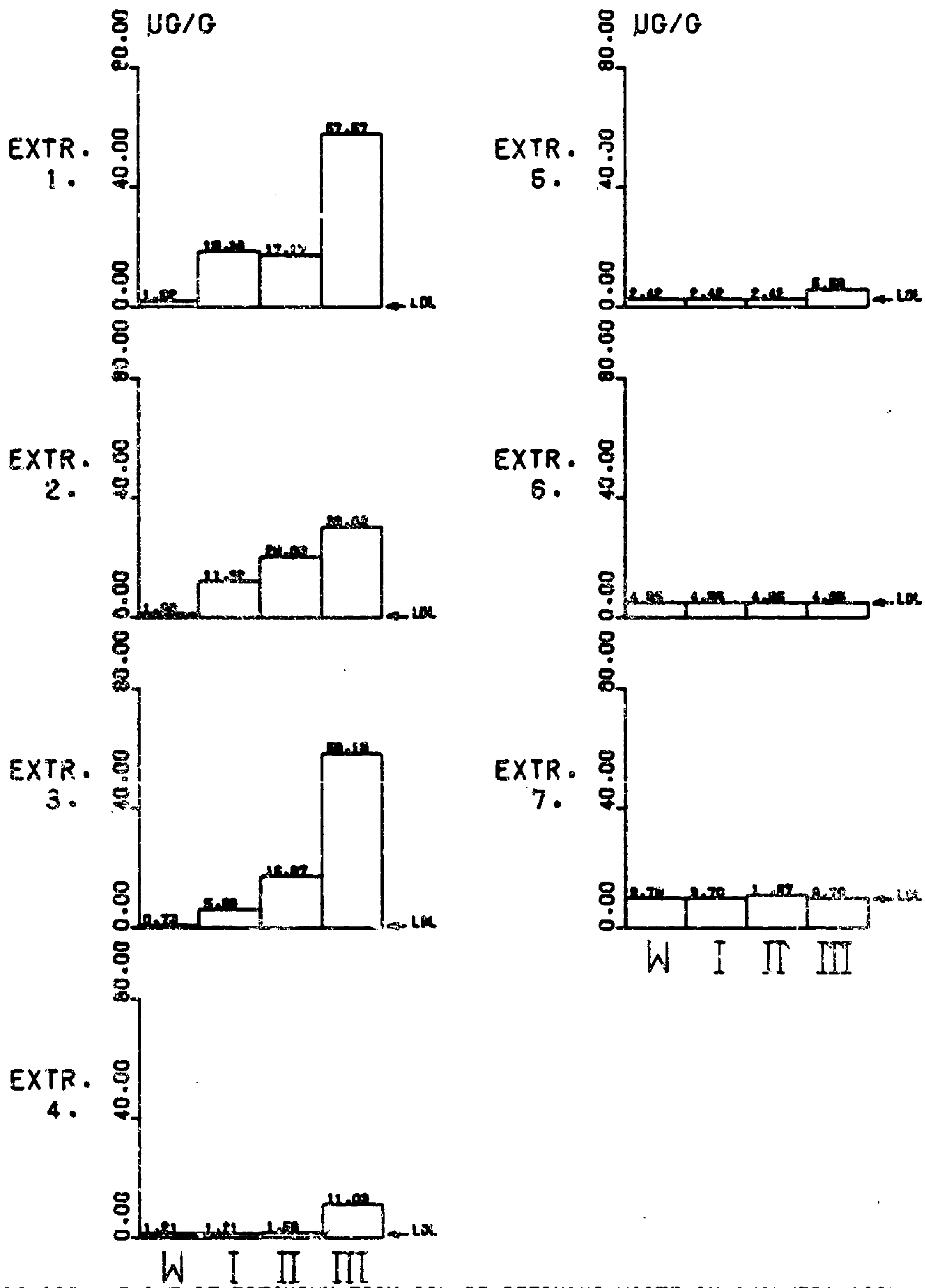

FIGURE 185. WEIGHT OF TITANIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 99. TITANIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.91	1.82										
	I	85.95	171.90	-170.08	1.82	-170.08	-93.56	-73.56	94.56	6.62	81.41	-.99	-44.70
	II	85.45	170.89	1.01	171.90	1.01	.01	.01	.99	7.66	82.56	.01	.34
	III	57.27	114.53	56.36	170.89	56.36	.33	.33	.67	11.91	85.20	.49	26.20
	I+II			-84.54	.91	-84.54	-93.00	-93.00	94.00	29.63	88.07	-.99	-44.69
	I+II+III			-37.57	.61	-37.57	-62.00	-62.00	63.00	101.80	89.44	-.98	-44.54
2	W	.33	1.00										
	I	19.39	58.16	-57.18	2.82	-227.26	-57.18	-80.65	58.18	18.58	86.92	-3.91	-75.64
	II	3.53	10.60	47.57	230.08	40.58	.82	.21	.18	127.92	89.55	4.58	77.69
	III	35.96	107.87	-97.26	101.50	-40.91	-9.17	-.23	10.17	11.75	85.13	-.38	-20.77
	I+II			-4.80	1.41	-89.34	-9.61	-63.41	10.61	476.50	89.88	-16.85	-86.60
	I+II+III			-35.62	.94	-73.19	-106.80	-77.92	100.	107.10	89.47	-2.04	-63.84
3	W	.12	.73										
	I	60.90	365.42	-364.69	3.55	-591.95	-501.50	-166.98	500.	1.96	62.96	-1.62	-58.31
	II	6.67	40.00	325.42	595.50	374.00	.89	.63	.11	42.05	88.64	9.35	83.90
	III	13.53	81.20	-41.21	221.49	-82.11	-1.03	-.37	2.03	15.10	86.21	-1.01	-45.32
	I+II			-19.63	1.77	-108.97	-54.00	-61.48	55.00	125.36	89.54	-5.45	-79.60
	I+II+III			-26.83	1.18	-100.02	-110.67	-84.64	111.	141.27	89.59	-3.70	-74.86
4	W	<.10	<1.21										
	I	.13	1.58	-.36	4.76	-592.31	-.30	-124.51	1.30	454.23	89.87	-375.93	-89.85
	II	.86	10.30	-8.73	597.07	365.28	-5.54	.61	6.54	162.42	89.65	35.46	88.38
	III	1.62	19.39	-9.09	231.80	-91.20	-.88	-.39	1.88	62.75	89.09	-4.70	-78.00
	I+II			-4.55	2.30	-113.52	-7.50	-47.73	8.50	465.82	89.88	-22.04	-87.40
	I+II+III			-6.06	1.59	-106.08	-15.00	-66.90	16.00	590.64	89.90	-16.41	-86.51
5	W	<.10	<2.42										
	I	<.10	<2.42										
	II	<.10	<2.42										
	III	<.10	<2.42										
	I+II												
	I+II+III												
6	W	<.10	<4.85										
	I	<.10	<4.85										
	II	<.10	<4.85										
	III	<.10	<4.85										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	.19	18.42										
	II	<.10	<9.70										
	III	<.10	<9.70										
	I+II												
	I+II+III												

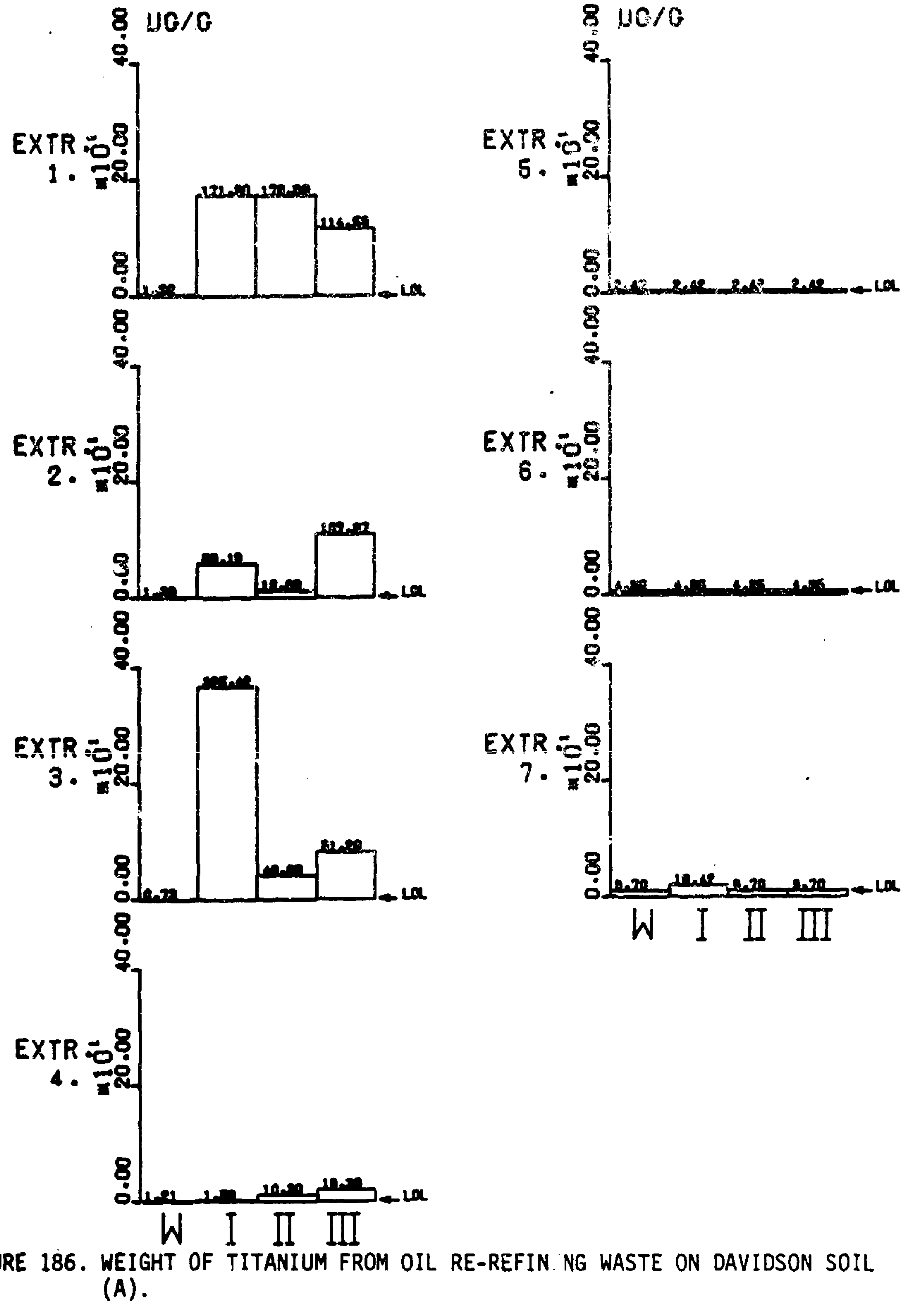

FIGURE 186. WEIGHT OF TITANIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 100. TITANIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.91	1.82										
	I	20.91	41.81	-40.00	1.82	-40.00	-22.00	-22.00	23.00	1.87	61.81	-.96	-43.73
	II	41.31	82.62	-40.80	41.81	-40.80	-.98	-.98	1.98	.93	43.06	-.49	-26.28
	III	21.41	42.82	39.79	82.62	39.79	.48	.48	.52	3.68	74.82	.93	42.90
	I+II			-40.40	.91	-40.40	-44.44	-44.44	45.44	4.74	78.07	-.98	-44.36
	I+II+III			-13.67	.61	-13.67	-22.56	-22.56	23.56	23.84	87.60	-.96	-43.76
2	W	.33	1.00										
	I	4.24	12.73	-11.73	2.82	-51.72	-11.73	-18.35	12.73	5.21	79.13	-4.06	-76.18
	II	6.87	20.60	-7.88	54.54	-40.68	-.62	-.89	1.62	3.36	73.45	-2.36	-67.06
	III	15.35	46.06	-25.45	103.22	14.34	-1.24	.14	2.24	2.87	70.81	.31	17.30
	I+II			-9.80	1.41	-50.20	-19.61	-35.63	20.61	18.04	86.83	-4.87	-78.40
	I+II+III			-15.02	.94	-28.69	-45.06	-30.54	46.06	21.19	87.30	-1.87	-61.85
3	W	.12	.73										
	I	1.21	7.27	-6.54	3.55	-58.27	-9.00	-16.44	10.00	8.21	83.06	-8.01	-82.89
	II	3.23	19.39	-12.12	61.81	-60.86	-1.67	-.98	2.67	2.95	71.27	-3.14	-72.31
	III	8.79	52.72	-33.33	122.61	-18.99	-1.72	-.15	2.72	1.88	61.97	-.36	-19.81
	I+II			-9.33	1.77	-59.53	-25.67	-33.59	26.67	18.20	86.86	-6.14	-80.75
	I+II+III			-17.33	1.18	-46.02	-71.50	-38.94	72.50	17.52	86.73	-2.62	-69.10
4	W	<.10	<1.21										
	I	<.10	<1.21										
	II	.70	8.36										
	III	1.01	12.12										
	I+II												
	I+II+III												
5	W	<.10	<2.42										
	I	<.10	<2.42										
	II	<.10	<2.42										
	III	<.10	<2.42										
	I+II												
	I+II+III												
6	W	<.10	<4.85										
	I	<.10	<4.85										
	II	<.10	<4.85										
	III	.11	5.33										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	<.10	<9.70										
	II	<.10	<9.70										
	III	<.10	<9.70										
	I+II												
	I+II+III												

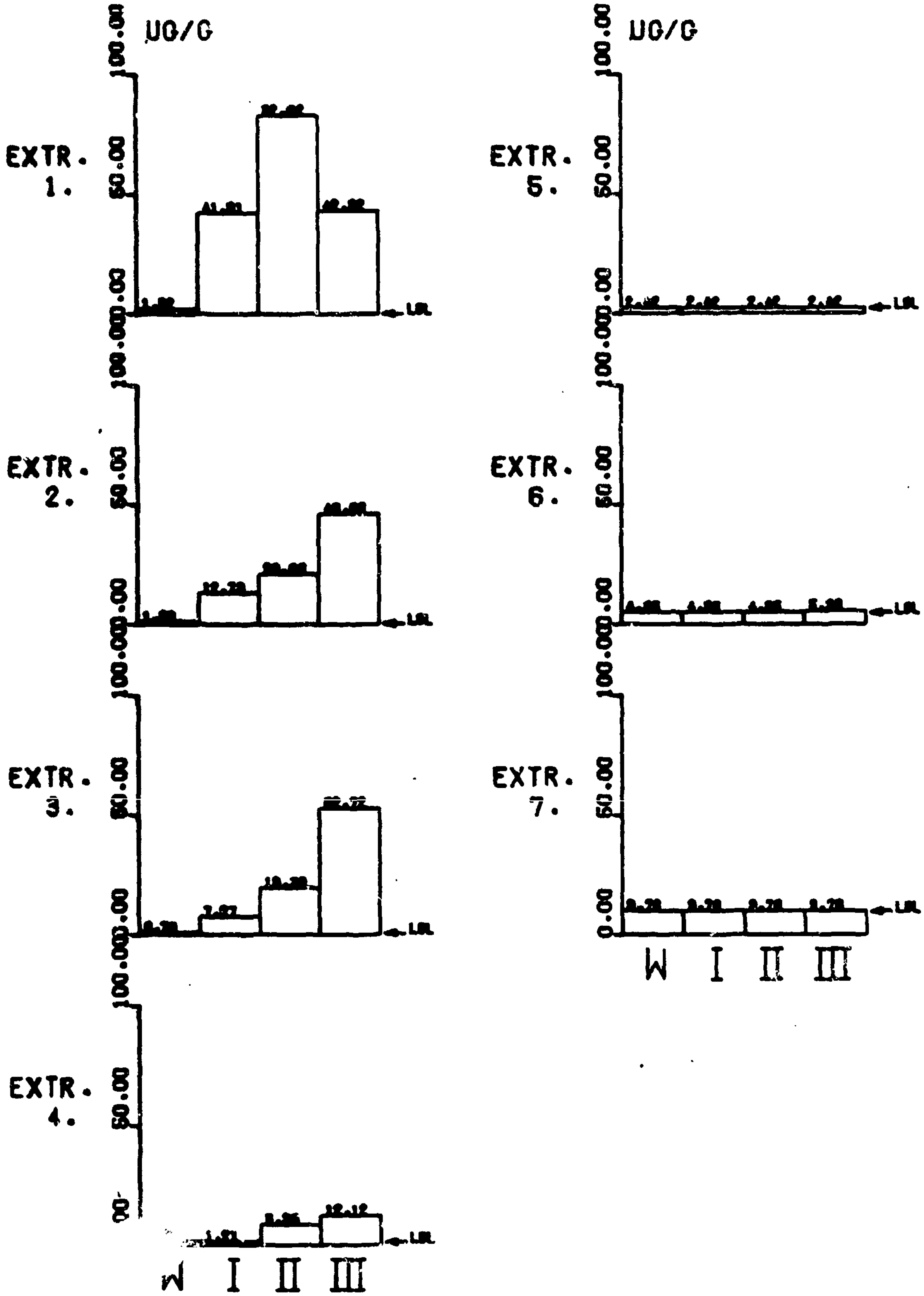

FIGURE 187. WEIGHT OF TITANIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

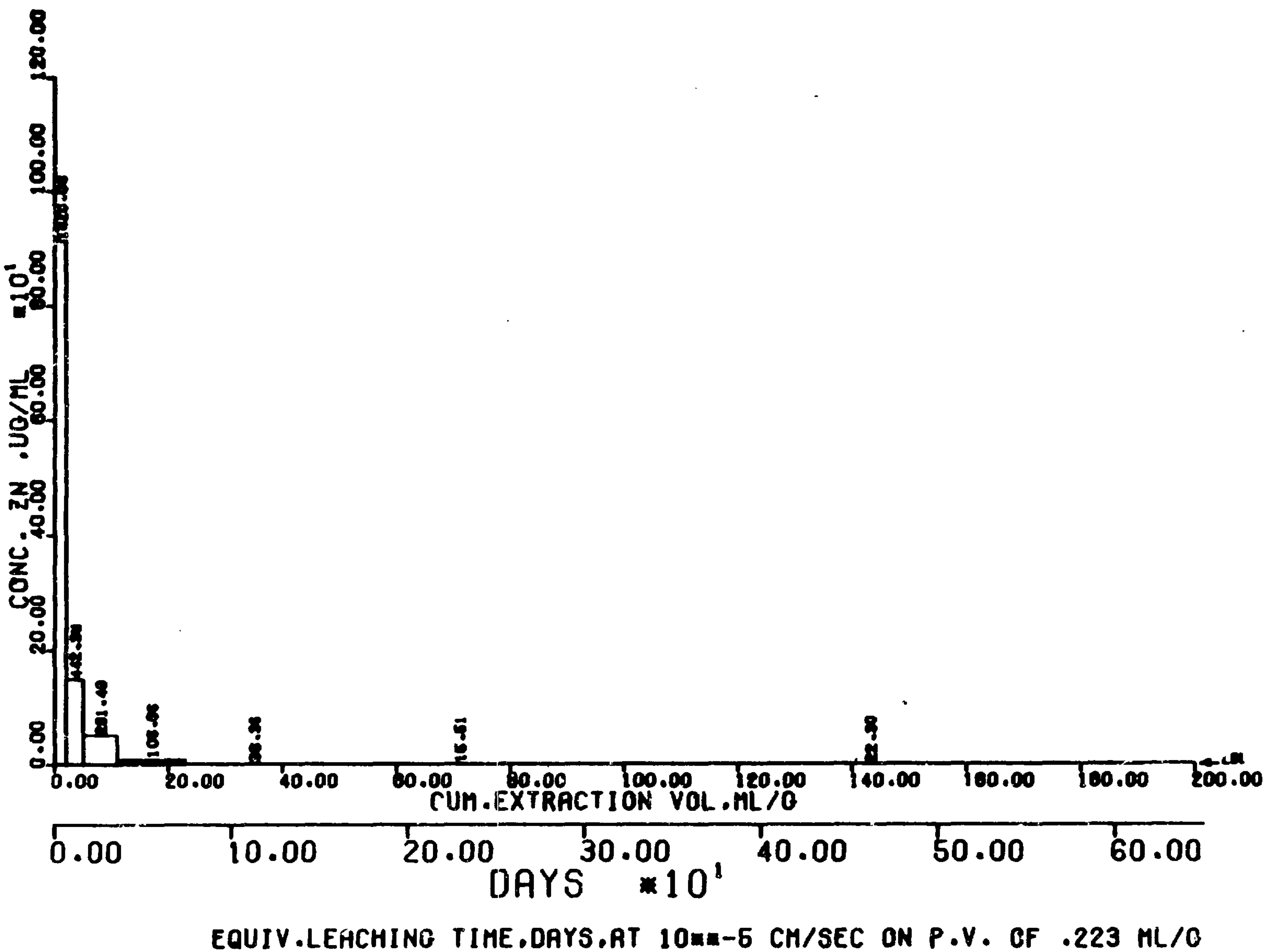

FIGURE 188. EXTRACTION OF ZINC FROM OIL RE-REFINING WASTE (A).

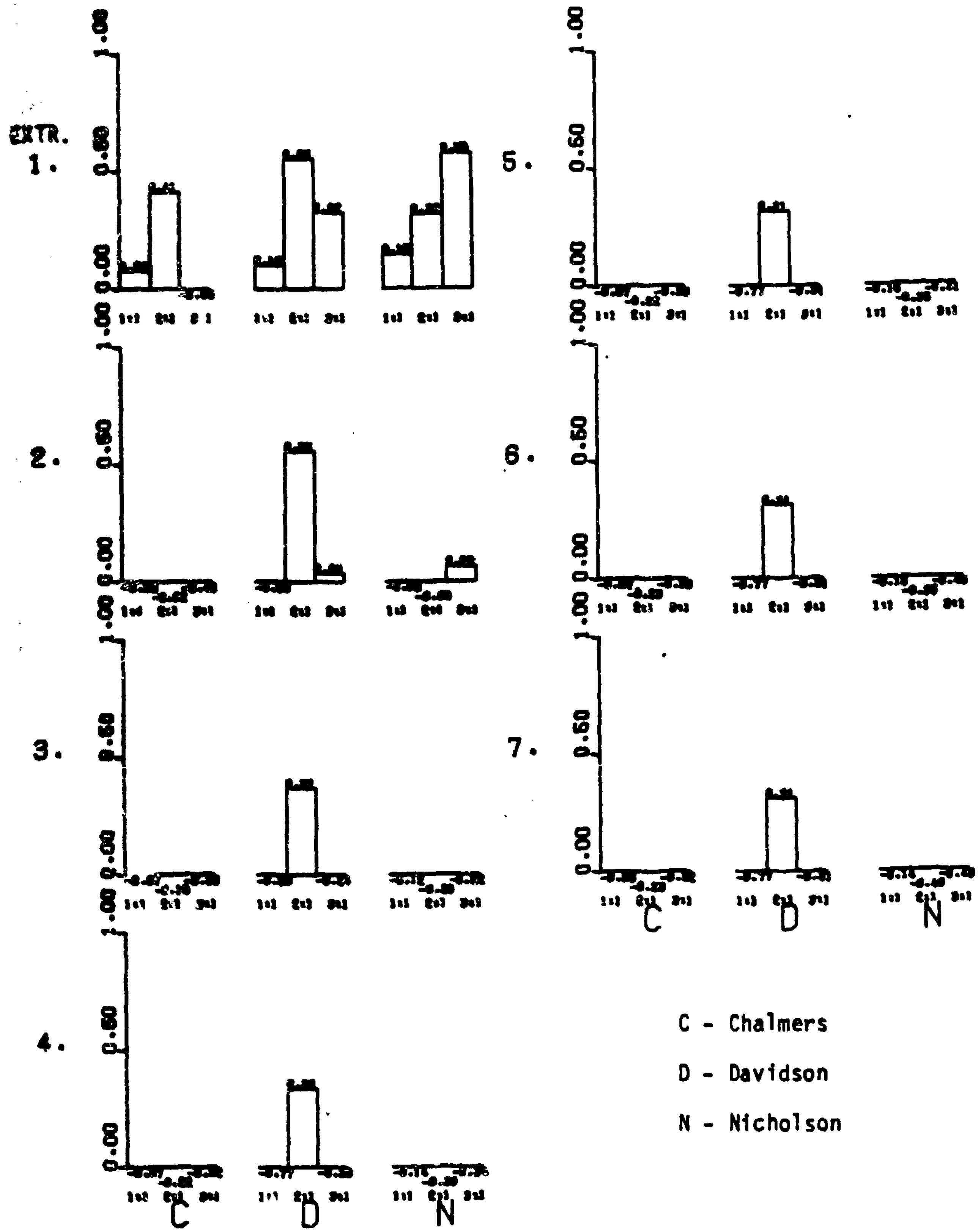

FIGURE 189. COMPARING FRACTION ZINC RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (A).

TABLE 101. ZINC FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

EXT.		AMT.PENETR.		AMT.RETD. THIS EXT.	CUM.TOT. CHALLG.	CUM.TOT. RETD.	FRACTION RETD.			DISTRIBUTION COEFFICIENTS			
							THIS	TOTAL	PENETR.	INCL SOIL		SOLN ONLY	
NR.	LAYER	UG/ML	UG/G	UG/G	UG/G	UG/G	EXTR.	CHALLG.	FACTOR	RATIO	DEG.	RATIO	DEC.
1	W	913.04	1826.00										
	I	905.37	1690.74	135.34	1826.00	135.34	.07	.07	.93	.12	6.65	.08	4.58
	II	580.33	1076.66	614.08	1690.74	614.08	.36	.36	.64	.63	32.12	.57	29.70
	III	916.07	1832.14	-755.48	1076.66	-755.48	-.70	-.70	1.70	-.34	-20.74	-.41	-22.41
	I+II			374.71	913.04	374.71	.41	.41	.59	.93	42.79	.70	34.84
	I+II+III			-2.02	608.69	-2.02	-.00	-.00	1.00	.30	16.71	-.00	-.19
2	W	147.46	442.38										
	I	193.92	581.76	-139.30	2260.46	-4.04	-.32	-.00	1.32	.10	5.67	-.01	-.40
	II	416.12	1248.36	-666.60	2272.50	-52.52	-1.15	-.02	2.15	.01	.43	-.04	-2.41
	III	509.04	1527.12	-270.76	2325.02	-1034.24	-.22	-.44	1.22	-.64	-32.49	-.68	-34.11
	I+II			-402.99	1134.23	-28.20	-1.02	-.02	2.02	.15	8.68	-.05	-2.59
	I+II+III			-361.58	756.15	-363.60	-2.45	-.40	3.45	-.35	-19.29	-.71	-35.54
3	W	40.58	271.49										
	I	76.26	457.53	-166.04	2597.95	-170.00	-.57	-.07	1.57	-.24	-13.32	-.37	-20.39
	II	119.18	715.00	-257.55	2730.03	-310.07	-.56	-.11	1.56	-.35	-19.15	-.43	-23.44
	III	233.31	1399.86	-684.70	3040.10	-1719.02	-.96	-.57	1.96	-1.10	-49.01	-1.23	-50.84
	I+II			-211.00	1279.77	-240.00	-1.45	-.19	2.45	-.33	-18.04	-.67	-33.80
	I+II+III			-309.46	853.32	-733.86	-3.00	-.86	4.00	-1.17	-49.57	-1.57	-57.52
4	W	8.09	106.66										
	I	10.00	119.99	-13.33	2666.60	-183.42	-.13	-.07	1.13	-1.01	-45.39	-1.53	-56.81
	II	18.18	218.16	-98.17	2858.02	-400.24	-.82	-.14	1.82	-1.59	-57.80	-1.87	-61.80
	III	29.59	355.12	-136.96	3258.26	-1855.90	-.63	-.57	1.63	-5.05	-78.00	-5.23	-79.17
	I+II			-55.75	1333.38	-275.83	-1.05	-.22	2.05	-1.58	-57.65	-2.71	-69.76
	I+II+III			-82.82	880.87	-815.00	-2.33	-.92	3.33	-5.33	-79.37	-6.89	-81.74
5	W	1.52	36.36										
	I	1.72	41.21	-4.85	2702.96	-180.26	-.13	-.07	1.13	-3.07	-71.95	-4.57	-77.65
	II	2.02	48.48	-7.27	2891.23	-415.51	-.18	-.14	1.18	-7.30	-82.20	-8.57	-83.35
	III	4.55	109.08	-60.60	3306.74	-1916.58	-1.25	-.58	2.25	-17.00	-86.63	-17.57	-86.74
	I+II			-6.06	1351.40	-301.09	-.33	-.22	1.33	-7.36	-82.26	-12.45	-85.41
	I+II+III			-24.24	900.99	-840.12	-2.00	-.93	3.00	-10.01	-86.82	-23.11	-87.52
6	W	.32	15.51										
	I	.29	14.06	1.45	2718.48	-186.81	.09	-.07	.91	-8.89	-83.58	-13.29	-85.70
	II	.91	43.63	-29.57	2905.29	-445.09	-2.10	-.15	3.10	-8.70	-83.51	-10.20	-84.40
	III	.69	32.97	10.67	3358.37	-1905.91	.24	-.57	.76	-55.94	-88.98	-57.81	-89.01
	I+II			-14.06	1359.24	-315.95	-1.01	-.23	2.01	-8.82	-83.53	-14.48	-86.05
	I+II+III			-5.82	906.16	-845.94	-1.12	-.93	2.12	-50.11	-89.05	-76.90	-89.26
7	W	.23	22.30										
	I	.14	13.57	8.73	2740.78	-178.08	.39	-.06	.61	-8.57	-83.34	-13.12	-85.64
	II	.12	11.64	1.94	2918.86	-443.15	.14	-.15	.86	-32.70	-88.25	-38.09	-88.50
	III	.19	18.42	-6.79	3362.01	-1912.70	-.58	-.57	1.58	-100.47	-89.43	-103.82	-89.45
	I+II			5.33	1370.39	-310.62	.48	-.23	.52	-32.15	-88.22	-53.39	-88.93
	I+II+III			1.29	913.59	-844.64	.17	-.92	.83	-107.35	-89.47	-137.55	-89.58

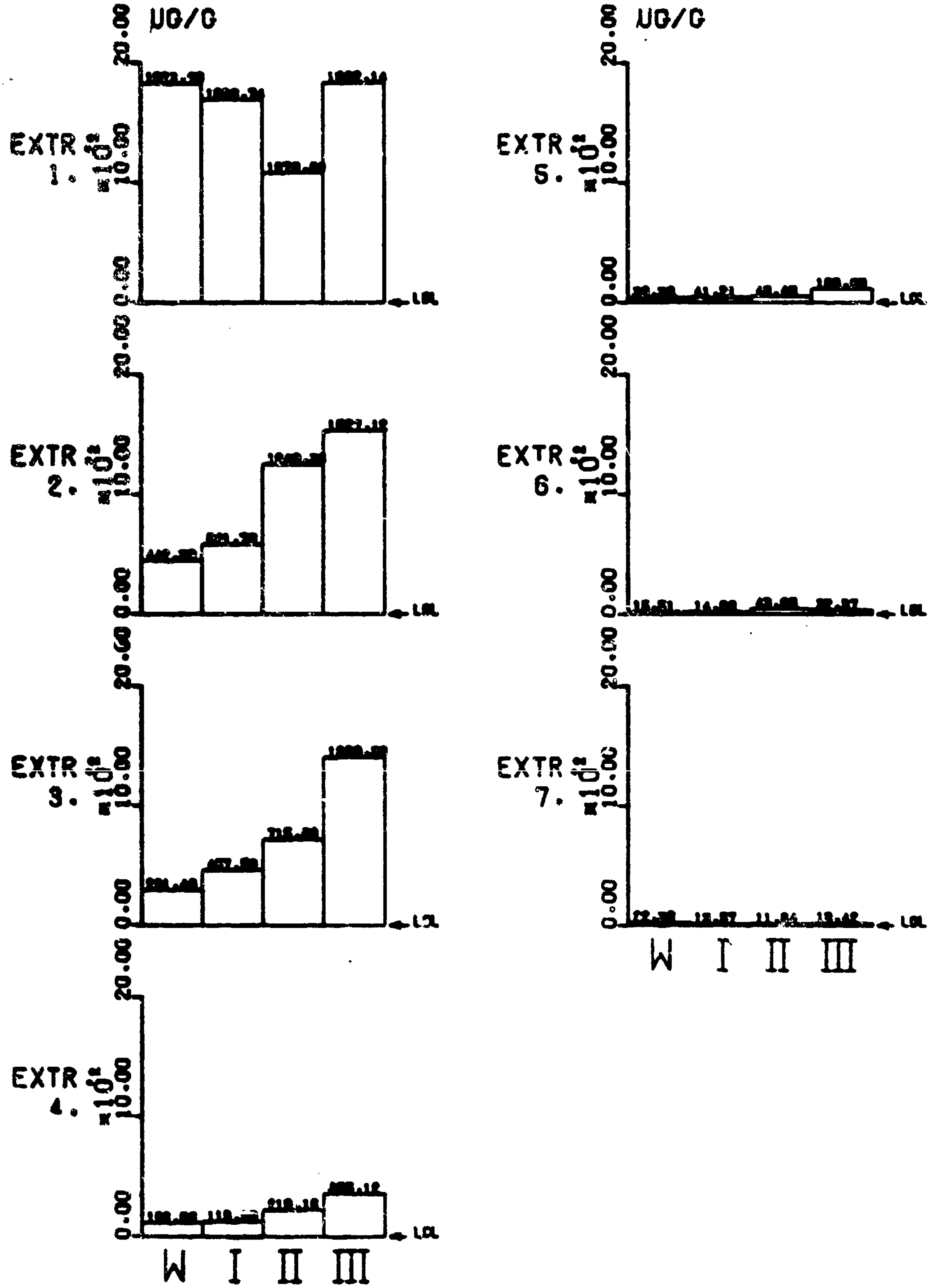

FIGURE 190. WEIGHT OF ZINC FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (A).

TABLE 102. ZINC FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	M	713.04	1026.00										
	I	423.15	1646.30	179.70	1026.00	179.70	.18	.18	.90	.14	8.12	.11	6.23
	II	461.07	822.14	824.16	1646.30	824.16	.50	.50	.50	1.07	46.92	1.00	45.07
	III	649.13	230.26	-416.12	822.14	-416.12	-.51	-.51	1.51	-.29	-16.26	-.34	-18.58
	I+II			501.97	913.04	501.97	.55	.55	.45	1.49	56.11	1.22	50.69
	I+II+III			195.94	608.69	195.94	.32	.32	.68	.87	41.17	.47	25.39
2	M	147.46	442.38										
	I	276.68	862.04	-369.66	2268.46	-189.08	-.04	-.08	1.04	-.17	-9.43	-.23	-13.16
	II	64.54	193.62	618.42	2458.34	1442.50	.76	.59	.24	7.73	82.63	7.45	82.36
	III	319.16	957.48	-763.86	1015.76	-1179.90	-3.95	-1.16	4.95	-1.17	-49.68	-1.23	-50.94
	I+II			124.38	1134.23	626.35	.56	.55	.44	7.61	82.51	6.47	81.21
	I+II+III			-171.70	756.15	24.24	-1.16	.03	2.16	.59	30.67	.08	4.34
3	M	48.58	291.49										
	I	357.58	2145.24	-1853.8	2559.95	-2043.63	-6.36	-.80	7.36	-.93	-42.83	-.95	-43.61
	II	108.97	605.39	1530.05	4603.58	2902.43	.72	.65	.28	5.02	78.73	4.93	78.53
	III	162.64	975.66	-370.27	1621.15	-1558.25	-.61	-.96	1.61	-1.53	-56.80	-1.59	-57.82
	I+II			-156.95	1279.97	469.40	-1.00	.37	2.00	1.91	62.42	1.55	57.18
	I+II+III			-228.06	853.32	-203.82	-2.35	-.24	3.35	-.12	-6.81	-.63	-32.08
4	M	8.89	106.66										
	I	8.69	104.[illegible]	2.42	2666.60	-2041.21	.02	-.77	.98	-19.06	-87.00	-19.50	-87.08
	II	13.13	157.56	-53.33	4707.04	2929.10	-.51	.62	1.51	18.94	86.98	18.59	86.92
	III	24.34	292.07	-134.58	1770.71	-1604.70	-.85	-.95	1.85	-5.58	-79.84	-5.77	-80.16
	I+II			-25.45	1333.30	443.95	-.40	.33	1.40	7.03	81.91	5.64	79.94
	I+II+III			-61.01	800.87	-265.63	-1.74	-.30	2.74	-1.03	-45.95	-2.73	-69.87
5	M	1.52	36.36										
	I	3.74	89.69	-53.33	2702.96	-2094.54	-1.47	-.77	2.47	-22.74	-87.48	-23.35	-87.55
	II	3.13	75.14	14.54	4797.50	2943.65	.16	.61	.84	39.91	88.56	39.17	88.54
	III	2.93	70.38	4.05	1853.06	-1679.93	.06	-.91	.94	-23.12	-87.52	-23.90	-87.60
	I+II			-19.39	1351.48	424.55	-1.07	.31	2.07	14.23	85.98	11.36	84.94
	I+II+III			-11.31	900.99	-276.94	-.93	-.31	1.93	-4.79	-78.18	-11.82	-85.16
6	M	.32	15.51										
	I	.40	19.39	-3.00	2718.40	-2098.42	-.25	-.77	1.25	-105.37	-89.46	-108.21	-89.47
	II	.54	25.69	-6.30	4016.09	2937.34	-.33	.61	1.33	116.46	89.51	114.32	89.50
	III	.73	34.91	-9.21	1879.55	-1689.14	-.36	-.90	1.36	-46.82	-88.78	-48.39	-88.82
	I+II			-5.09	1359.24	419.46	-.66	.31	1.66	41.21	88.61	32.65	88.25
	I+II+III			-6.46	906.16	-283.41	-1.25	-.31	2.25	-10.18	-84.39	-24.36	-87.65
7	M	.23	22.30										
	I	.23	22.30	.00	2740.78	-2098.42	.00	-.77	1.00	-91.63	-89.37	-94.10	-89.39
	II	.20	19.39	2.91	4039.19	2940.25	.13	.61	.87	154.46	89.63	151.62	89.62
	III	.19	18.42	.97	1898.94	-1680.18	.05	-.89	.95	-88.65	-89.35	-91.64	-89.37
	I+II			1.45	1370.39	420.92	.13	.31	.87	54.76	88.95	43.41	88.68
	I+II+III			1.29	913.59	-282.11	.17	-.31	.83	-19.07	-87.00	-45.94	-88.75

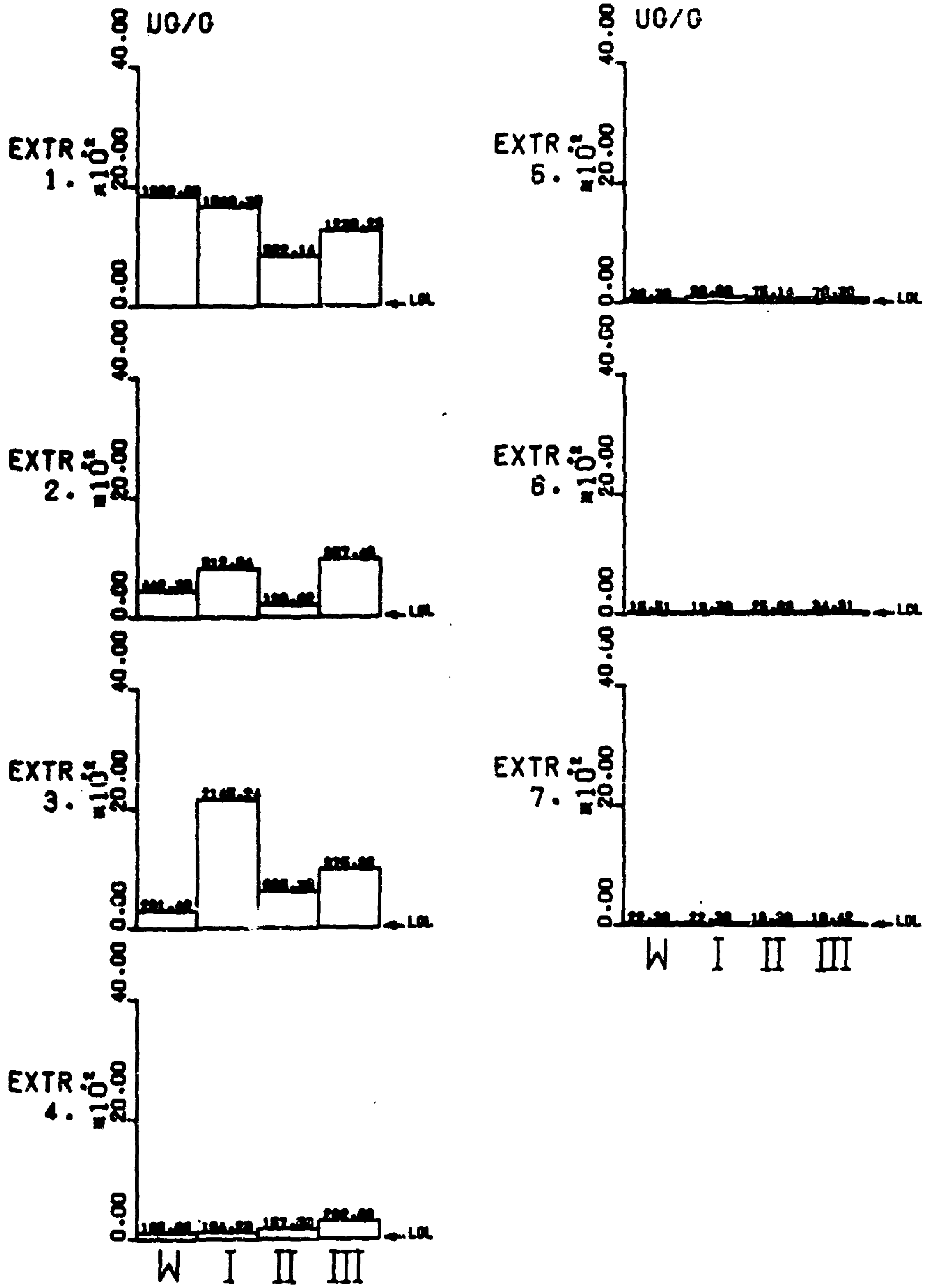

FIGURE 191. WEIGHT OF ZINC FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (A).

TABLE 103. ZINC FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	913.04	1826.00										
	I	779.72	1559.44	266.64	1826.00	266.64	.15	.15	.85	.22	12.35	.17	9.70
	II	623.17	1246.34	313.10	1559.44	313.10	.20	.20	.80	.31	17.29	.25	14.10
	III	387.84	775.68	470.66	1246.34	470.66	.38	.38	.62	.70	35.11	.61	31.25
	I+II			289.87	913.04	289.87	.32	.32	.68	.71	35.19	.47	24.95
	I+II+III			350.13	608.69	350.13	.58	.58	.42	2.22	65.77	1.35	53.56
2	W	147.46	442.38										
	I	280.78	842.34	-399.96	2268.46	-133.32	-.90	-.06	1.90	-.07	-3.97	-.16	-8.99
	II	412.08	1236.24	-393.90	2401.78	-80.80	-.47	-.03	1.47	-.00	-.28	-.07	-3.74
	III	450.44	1351.30	-115.14	2482.58	355.52	-.09	.14	1.09	.32	17.66	.26	14.74
	I+II			-396.93	1134.23	-107.06	-1.79	-.09	2.79	.07	3.94	-.17	-9.83
	I+II+III			-303.00	754.15	47.13	-2.05	.06	3.05	.60	31.08	.10	5.97
3	W	40.58	291.49										
	I	77.77	466.62	-175.13	2559.95	-308.45	-.60	-.12	1.60	-.50	-26.60	-.66	-33.47
	II	131.30	787.80	-321.10	2868.40	-401.98	-.69	-.14	1.69	-.42	-22.55	-.51	-27.03
	III	165.64	993.84	-206.04	3270.38	149.48	-.26	.05	1.26	.23	12.72	.15	8.55
	I+II			-248.16	1279.97	-355.22	-1.70	-.20	2.70	-.52	-27.56	-.90	-42.04
	I+II+III			-234.12	853.32	-106.98	-2.41	-.22	3.41	.11	6.44	-.56	-29.44
4	W	8.89	106.66										
	I	15.35	184.22	-77.57	2666.60	-386.02	-.73	-.14	1.73	-1.69	-59.38	-2.10	-64.49
	II	22.32	267.85	-83.63	3052.62	-485.61	-.45	-.16	1.45	-1.53	-56.90	-1.81	-61.12
	III	37.57	450.86	-183.01	3538.23	-33.53	-.68	-.01	1.68	.09	5.23	-.07	-4.25
	I+II			-80.60	1333.30	-435.82	-1.51	-.33	2.51	-2.14	-64.92	-3.25	-72.92
	I+II+III			-114.74	888.87	-301.72	-3.23	-.34	4.23	-.51	-27.23	-2.01	-63.52
5	W	1.52	36.36										
	I	1.82	43.63	-7.27	2702.96	-393.29	-.20	-.15	1.20	-7.30	-82.20	-9.01	-83.67
	II	4.95	118.78	-75.14	3096.26	-560.75	-1.72	-.18	2.72	-4.09	-76.27	-4.72	-78.04
	III	10.10	242.40	-123.62	3657.01	-157.16	-1.04	-.04	2.04	-.34	-18.77	-.65	-32.96
	I+II			-41.21	1351.48	-477.02	-2.27	-.35	3.27	-5.51	-79.72	-8.03	-82.90
	I+II+III			-68.68	900.99	-370.40	-5.67	-.41	6.67	-1.81	-61.04	-4.58	-77.69
6	W	.32	15.51										
	I	.42	20.36	-4.85	2718.48	-398.14	-.31	-.15	1.31	-15.88	-86.40	-19.55	-87.07
	II	.52	24.72	-4.36	3116.62	-565.12	-.21	-.18	1.21	-19.83	-87.11	-22.86	-87.49
	III	1.52	72.72	-48.10	3681.73	-205.15	-1.94	-.06	2.94	-1.79	-60.84	-2.82	-70.48
	I+II			-4.61	1359.24	-481.63	-.59	-.35	1.59	-26.86	-87.87	-38.96	-88.53
	I+II+III			-19.07	906.16	-389.47	-3.69	-.43	4.69	-6.81	-81.65	-16.87	-86.44
7	W	.23	22.30										
	I	.08	7.76	14.54	2740.78	-383.60	.65	-.14	.35	-39.81	-88.56	-49.45	-88.84
	II	1.62	155.14	-147.38	3124.37	-712.49	-19.00	-.23	20.00	-4.11	-76.33	-4.59	-77.72
	III	.32	31.03	124.11	3836.87	-81.04	.80	-.02	.20	-.20	-11.38	-2.61	-69.05
	I+II			-66.42	1370.39	-548.05	-5.96	-.40	6.96	-5.14	-78.98	-7.07	-81.94
	I+II+III			-2.91	913.59	-392.38	-.39	-.43	1.39	-16.24	-86.48	-37.94	-88.49

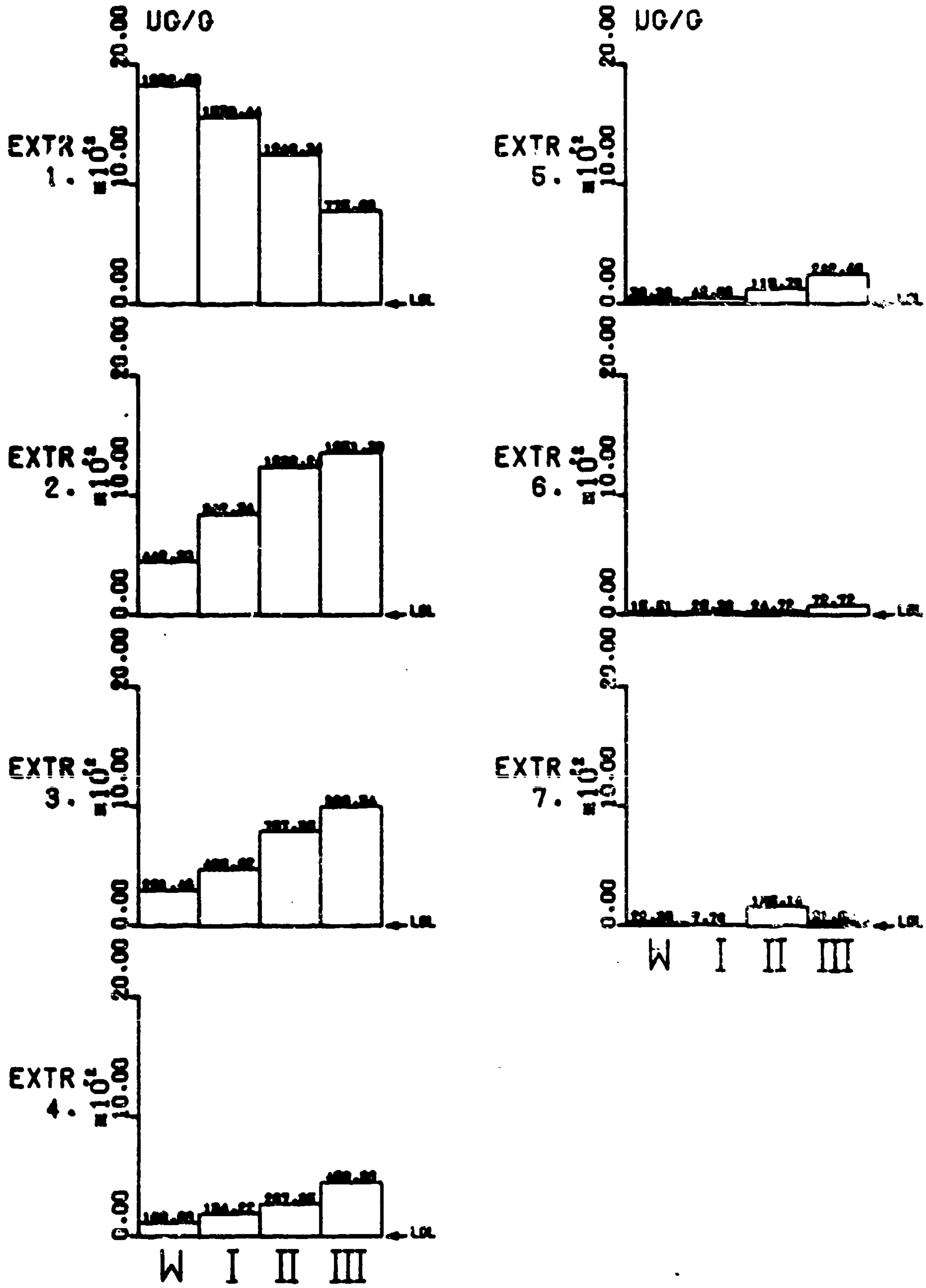

FIGURE 192. WEIGHT OF ZINC FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (A).

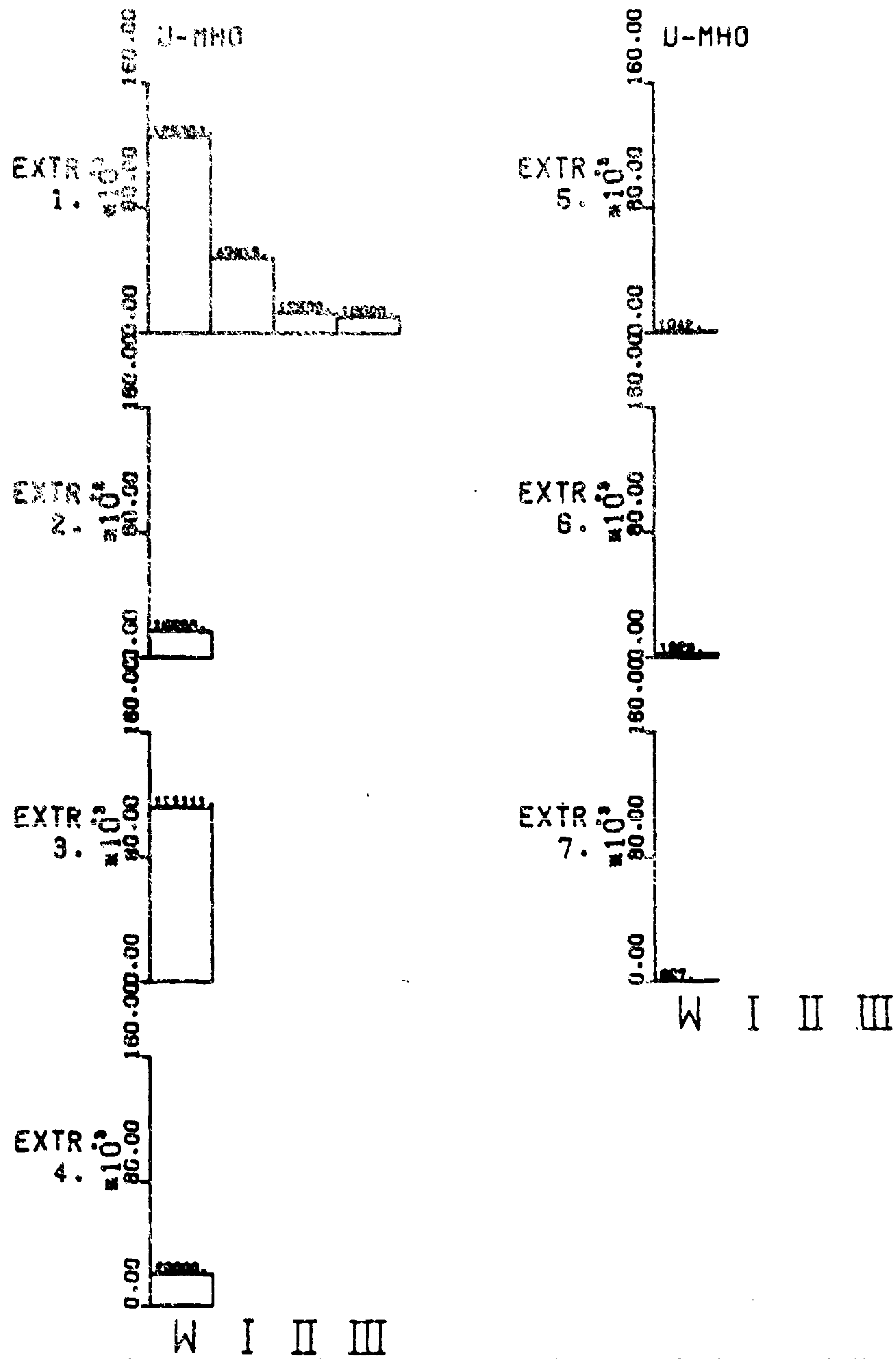

FIGURE 193. CONDUCTANCE OF EXTRACT FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

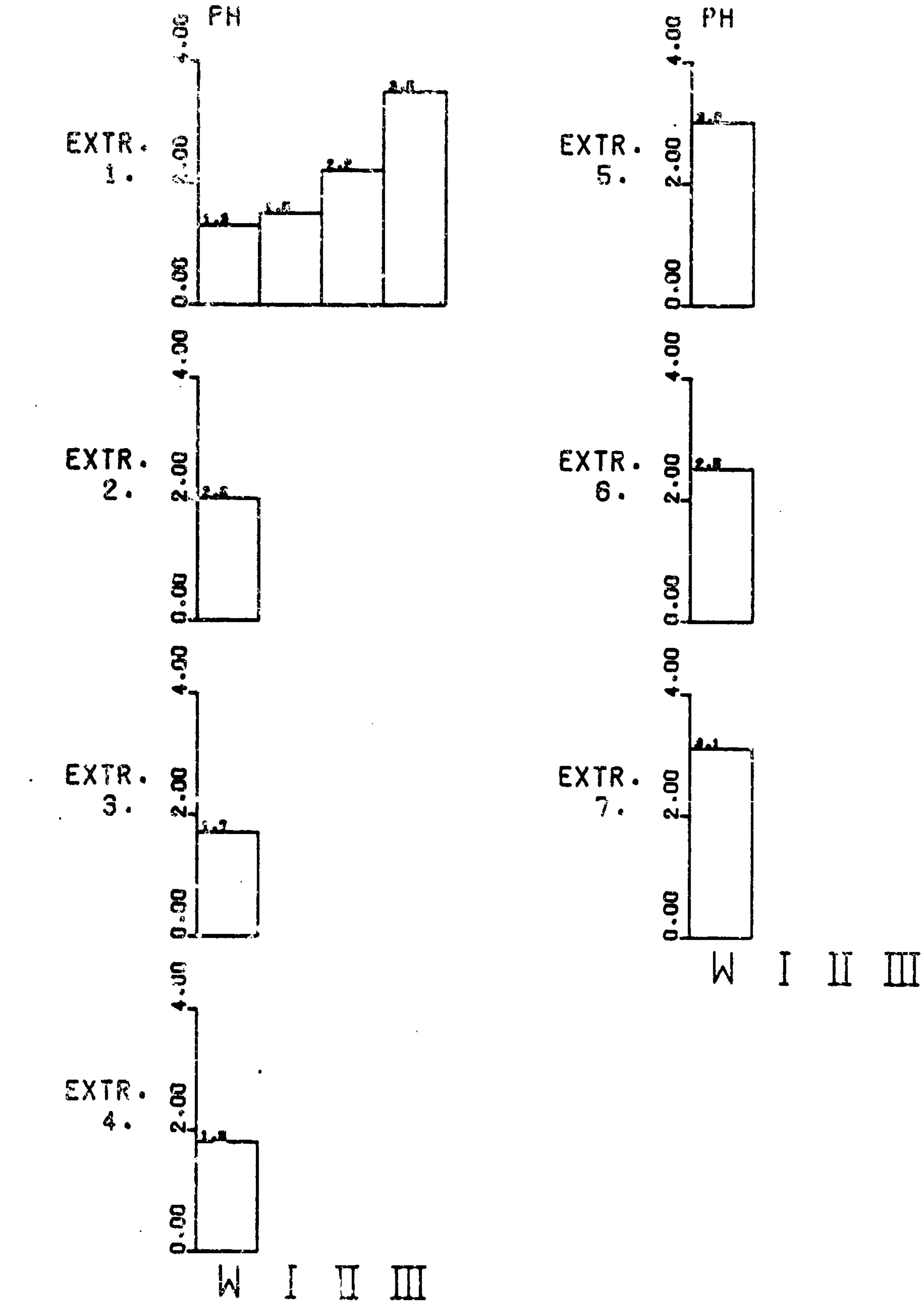

FIGURE [illegible]4. pH OF EXTRACT FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

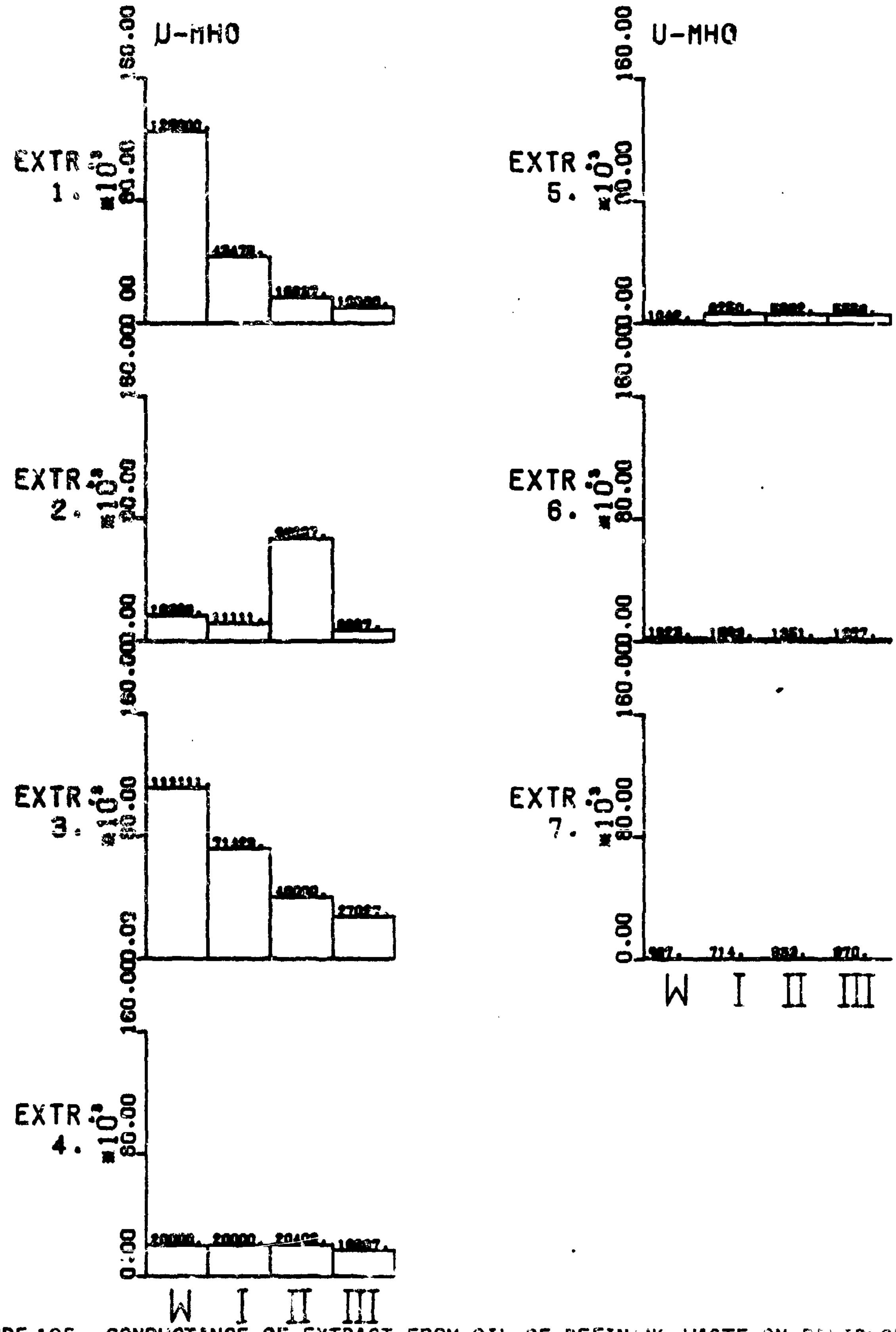

FIGURE 195. CONDUCTANCE OF EXTRACT FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

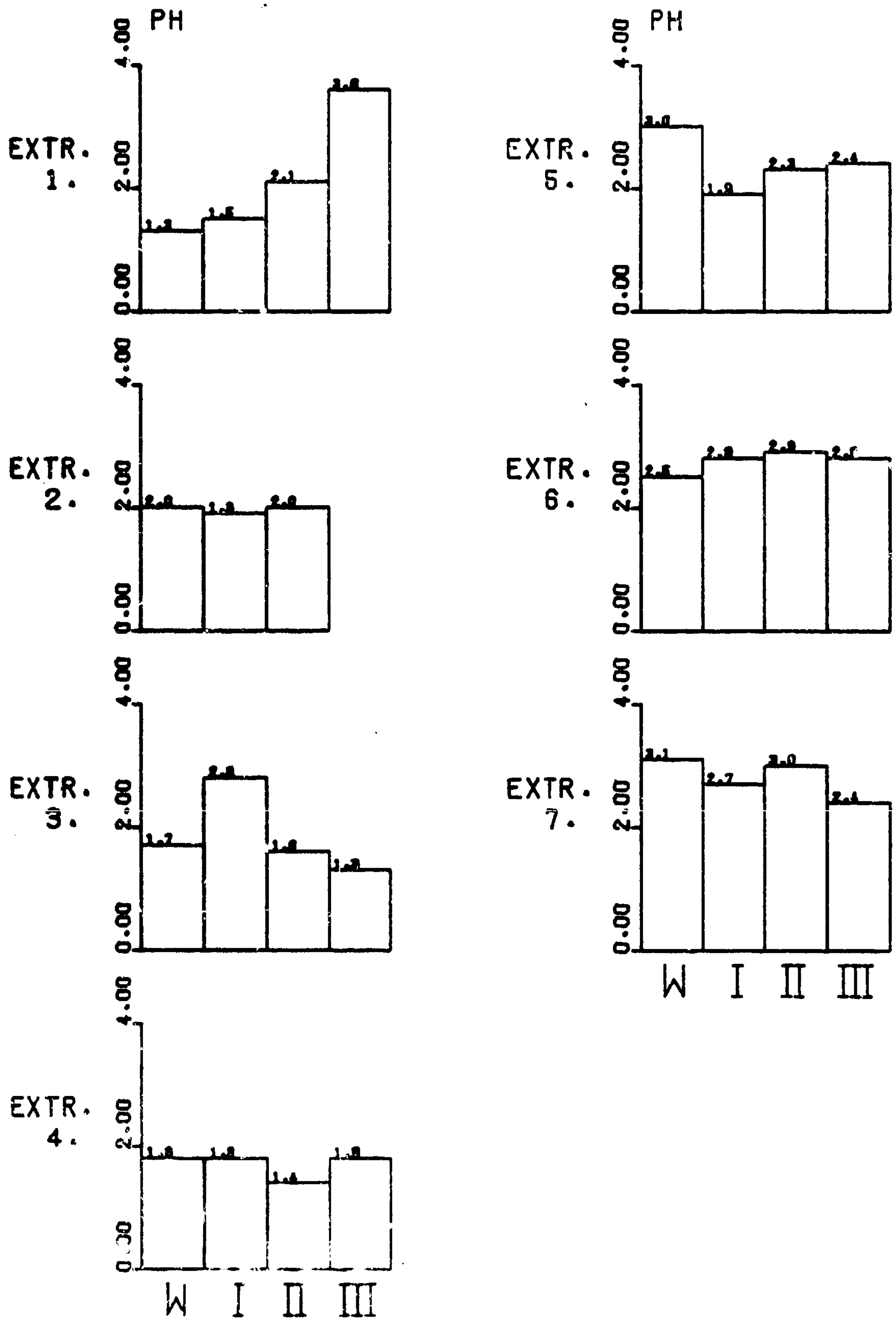

FIGURE 196. pH OF EXTRACT FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

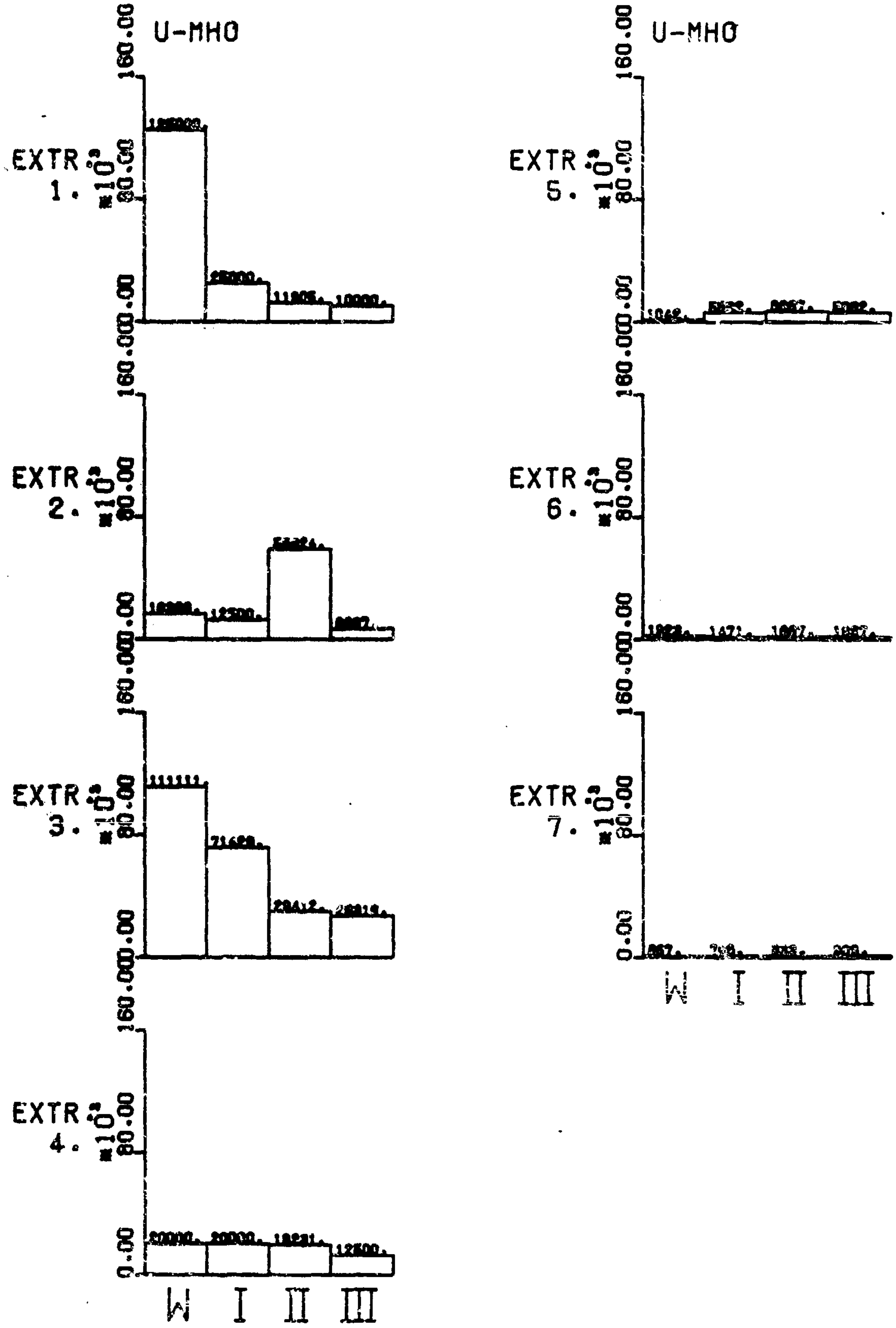

FIGURE 197. CONDUCTANCE OF EXTRACT FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

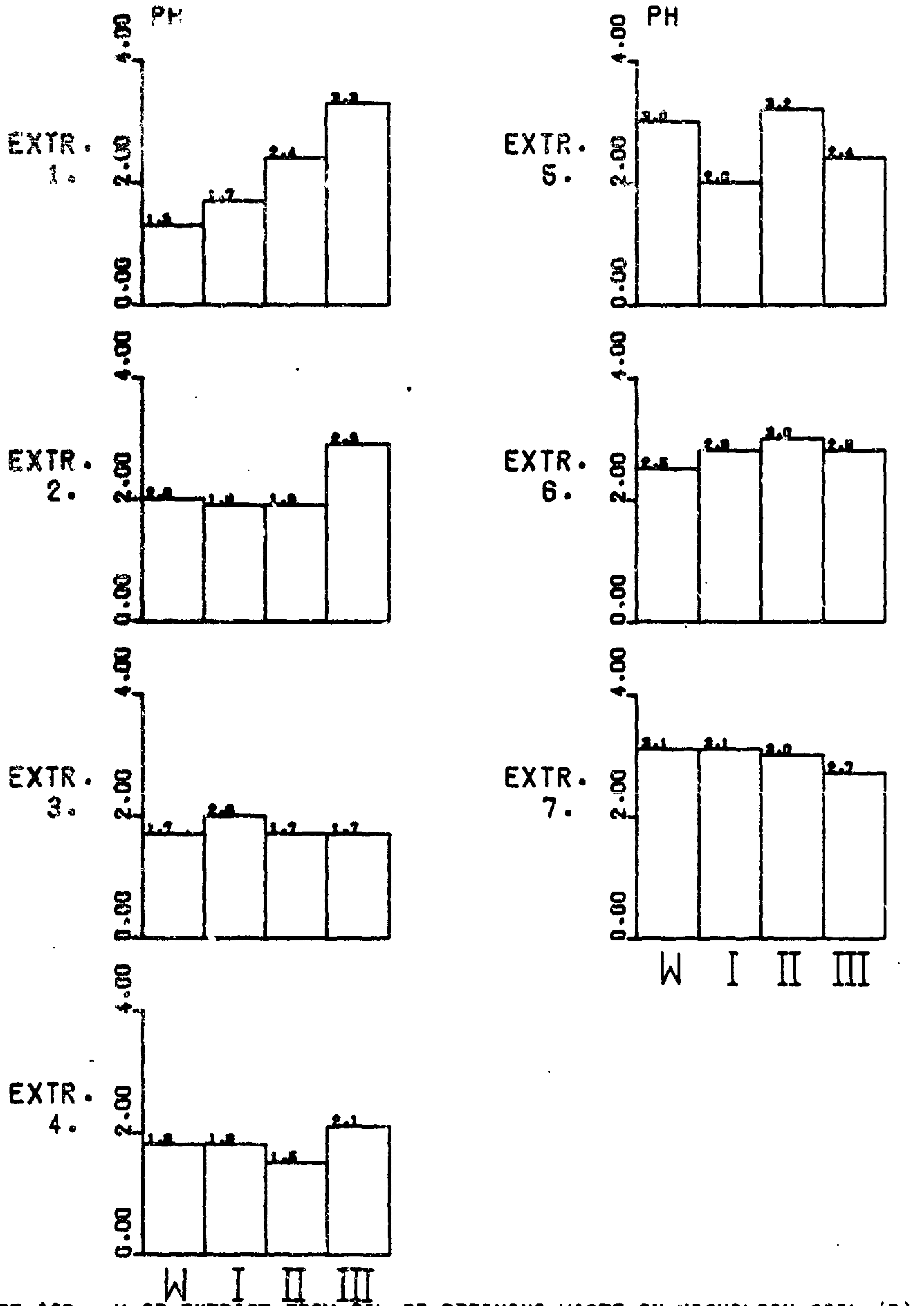

FIGURE 198. pH OF EXTRACT FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

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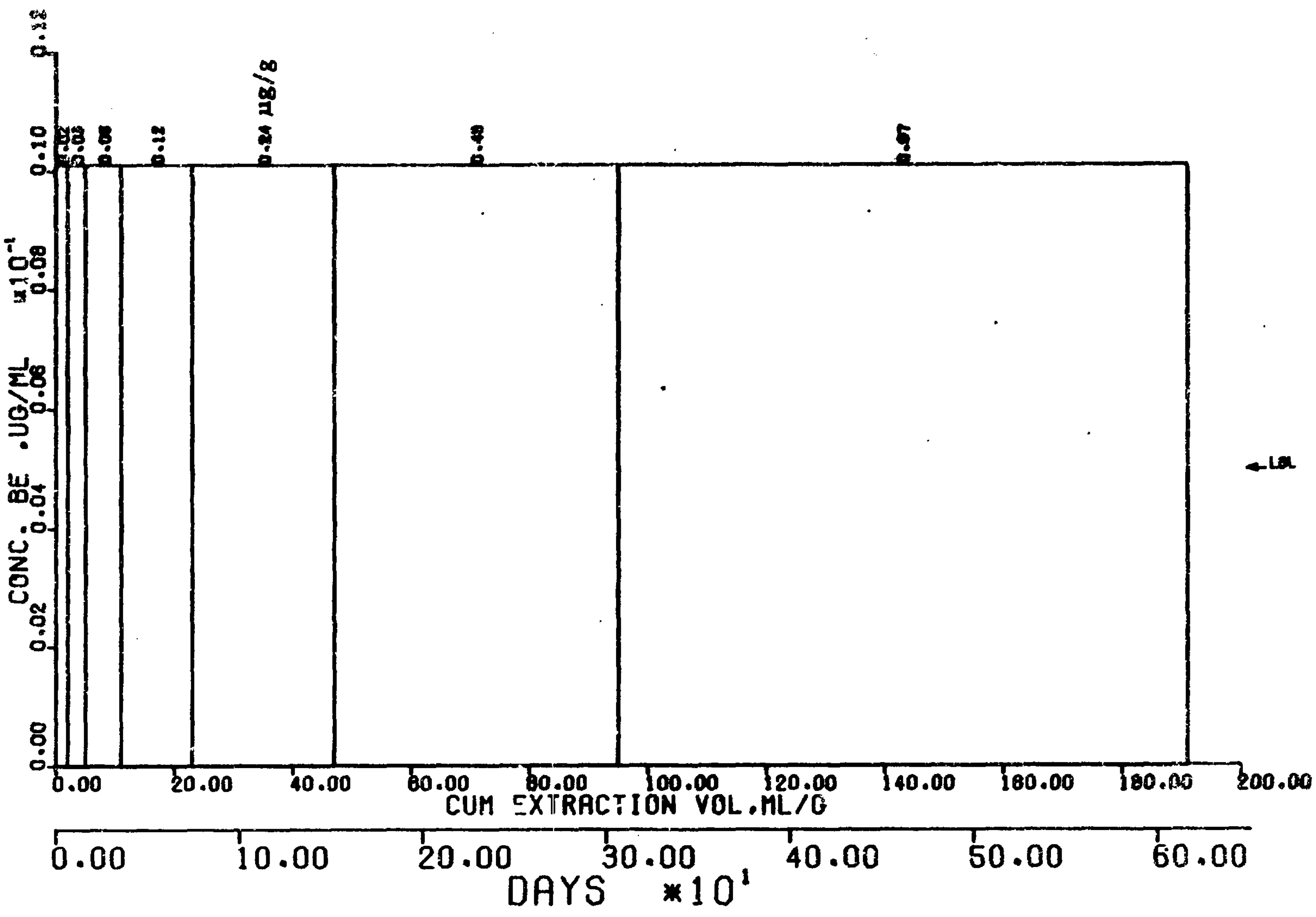


EQUIV.LEACHING TIME.DAYS.AT 10**-5 CM/SEC ON P.V. OF .223 ML/G

FIGURE 199. EXTRACTION OF BERYLLIUM FROM OIL RE-REFINING WASTE (B).

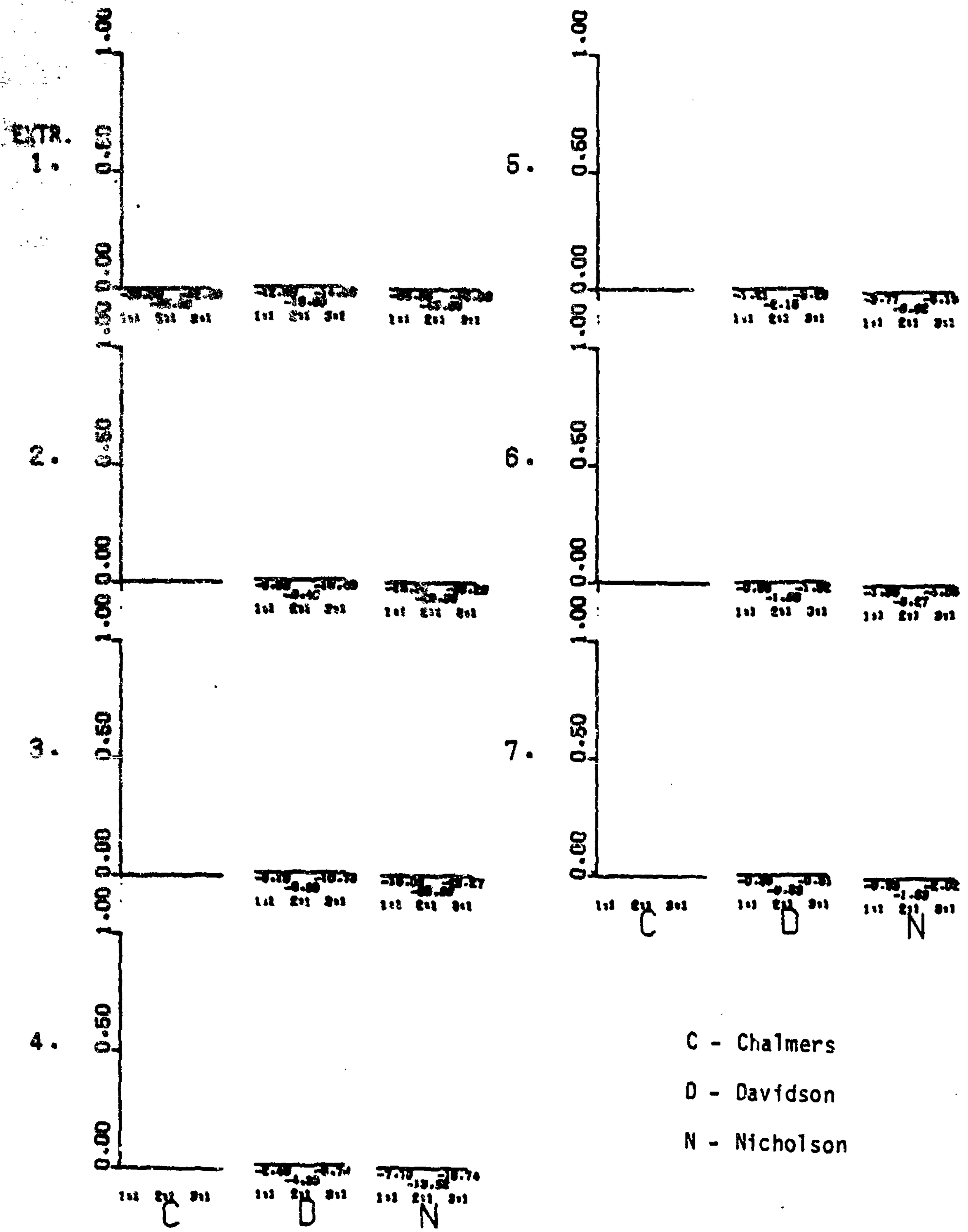


FIGURE 200. COMPARING FRACTION BERYLLIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 104. BERYLLIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	ANT. PENETR. UG/ML	ANT. PENETR. UG/G	ANT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHAL.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.01	.02										
	I	.29	.59	-.57	.02	-.57	-28.00	-28.00	29.00	2.96	71.34	-.97	-43.99
	II	.36	.73	-.14	.59	-.14	-.24	-.24	1.24	2.97	71.38	-.19	-11.00
	III	.43	.87	-.14	.73	-.14	-.19	-.19	1.19	2.49	68.08	-.16	-9.25
	I+II			-.35	.01	-.35	-35.00	-35.00	36.00	11.68	85.11	-.97	-44.19
	I+II+III			-.28	.01	-.28	-42.00	-42.00	43.00	22.85	87.49	-.98	-44.33
2	W	.01	.03										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	.01	.06										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	.01	.12										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	.01	.24										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	.01	.48										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	.01	.97										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

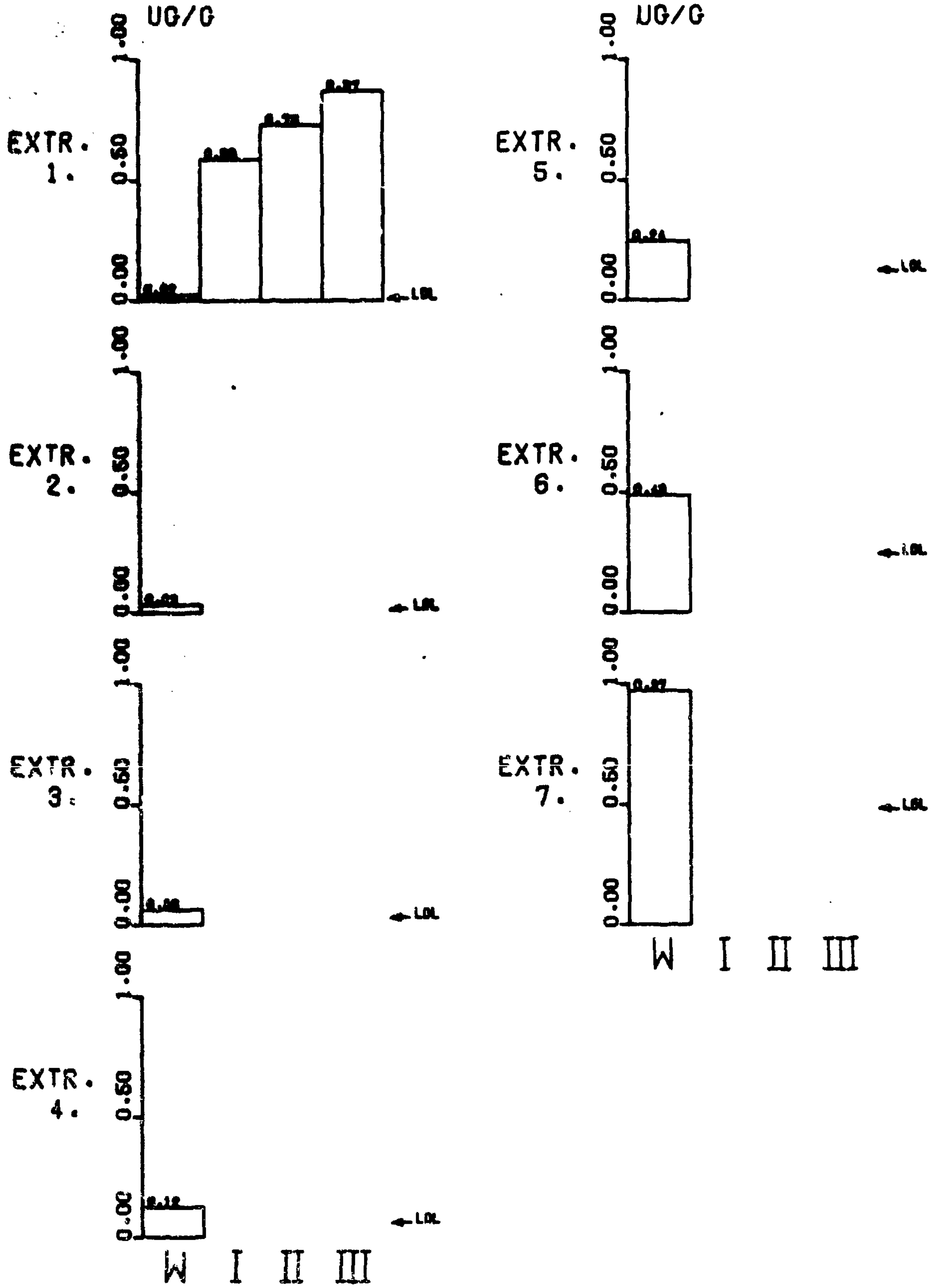


FIGURE 201. WEIGHT OF BERYLLIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 105. BERYLLIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLS. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.01	.02										
	I	.13	.26	-.24	.02	-.24	-12.00	-12.00	13.00	10.69	84.66	-.92	-42.71
	II	.17	.34	-.08	.26	-.08	-.31	-.31	1.31	8.65	83.40	-.24	-13.24
	III	.15	.30	.04	.34	.04	.12	.12	.88	10.20	84.40	.13	7.59
	I+II			-.16	.01	-.16	-16.00	-16.00	17.00	34.59	88.34	-.94	-43.26
	I+II+III			-.09	.01	-.09	-14.00	-14.00	15.00	89.66	89.36	-.93	-43.03
2	W	.01	.03										
	I	.04	.12	-.09	.05	-.33	-3.00	-6.60	4.00	22.42	87.[illegible]	-2.75	-70.02
	II	.06	.30	-.06	.30	-.14	-.50	-.37	1.50	16.00	86.42	-.70	-37.87
	III	.09	.27	-.09	.53	-.05	-.50	-.10	1.50	11.00	84.81	-.19	-10.49
	I+II			-.08	.03	-.24	-5.00	-9.40	6.00	64.50	89.11	-2.61	-69.04
	I+II+III			-.08	.02	-.18	-8.00	-10.40	9.00	98.73	89.42	-1.93	-62.56
3	W	.01	.06										
	I	.05	.30	-.24	.11	-.58	-4.60	-5.10	5.00	8.17	83.02	-1.90	-62.24
	II	.08	.40	-.10	.69	-.32	-.60	-.47	1.60	5.62	79.92	-.67	-33.69
	III	.12	.73	-.24	1.01	-.29	-.56	-.29	1.50	3.79	75.22	-.40	-21.94
	I+II			-.21	.06	-.45	-7.00	-8.09	8.00	23.31	87.54	-1.85	-61.66
	I+II+III			-.22	.04	-.40	-11.00	-10.73	12.00	36.11	88.41	-1.64	-58.61
4	W	.01	.12										
	I	.01	.12	.00	.23	-.58	.00	-2.40	1.00	26.42	87.20	-4.75	-78.11
	II	.02	.24	-.12	.81	-.44	-1.00	-.55	2.00	10.75	84.69	-1.83	-61.39
	III	.04	.40	-.24	1.25	-.54	-1.00	-.43	2.00	5.19	79.09	-1.10	-47.83
	I+II			-.06	.12	-.51	-1.00	-4.39	2.00	46.12	88.76	-4.21	-76.63
	I+II+III			-.12	.08	-.52	-3.00	-6.70	4.00	53.41	88.93	-3.21	-72.69
5	W	.01	.24										
	I	.01	.24	.00	.47	-.58	.00	-1.21	1.00	10.21	84.40	-2.38	-67.17
	II	.01	.24	.00	1.05	-.44	.00	-.42	1.00	10.75	84.69	-1.83	-61.39
	III	.01	.24	.00	1.49	-.54	.00	-.36	1.00	10.37	84.49	-2.21	-65.64
	I+II			.00	.24	-.51	.00	-2.15	1.00	46.12	88.76	-4.21	-76.63
	I+II+III			.00	.16	-.52	.00	-3.28	1.00	106.83	89.46	-6.42	-81.14
6	W	.01	.40										
	I	.01	.40	.00	.96	-.58	.00	-.60	1.00	5.10	78.91	-1.19	-49.90
	II	.01	.40	.00	1.54	-.44	.00	-.29	1.00	5.37	79.46	-.92	-42.51
	III	.01	.40	.00	1.98	-.54	.00	-.27	1.00	5.19	79.09	-1.10	-47.83
	I+II			.00	.40	-.51	.00	-1.06	1.00	23.06	87.52	-2.10	-64.58
	I+II+III			.00	.32	-.52	.00	-1.62	1.00	53.41	88.93	-3.21	-72.69
7	W	.01	.97										
	I	.01	.97	.00	1.93	-.58	.00	-.30	1.00	2.55	68.60	-.59	-30.70
	II	.01	.97	.00	2.50	-.44	.00	-.18	1.00	2.69	69.59	-.46	-24.62
	III	.01	.97	.00	2.95	-.54	.00	-.18	1.00	2.59	68.91	-.55	-28.90
	I+II			.00	.96	-.51	.00	-.53	1.00	11.53	85.04	-1.05	-46.45
	I+II+III			.00	.64	-.52	.00	-.81	1.00	26.71	87.86	-1.60	-58.06

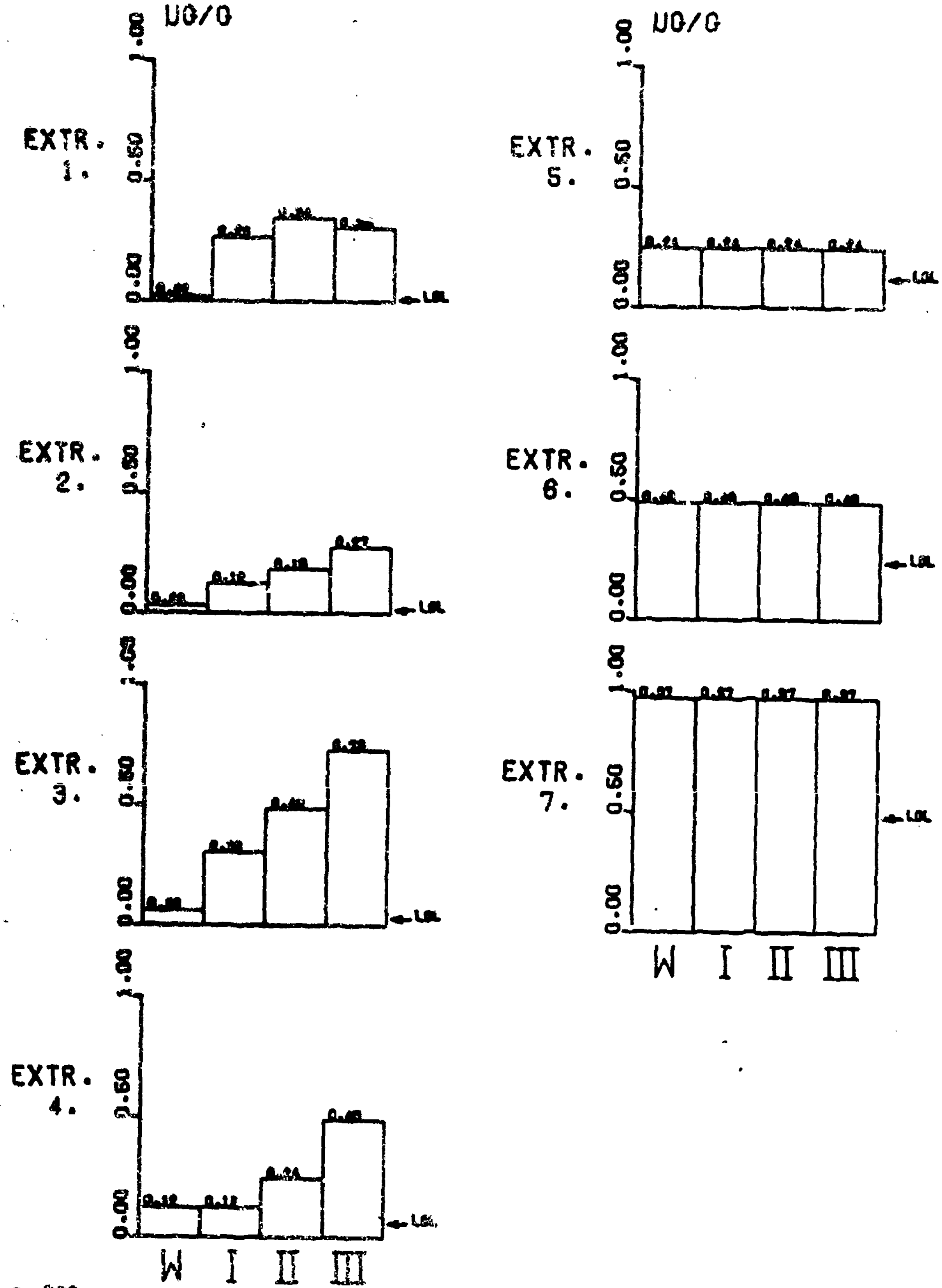


FIGURE 202. WEIGHT OF BERYLLIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 106. BERYLLIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.01	.02										
	I	.34	.69	-.67	.02	-.67	-33.00	-33.00	34.00	3.76	75.11	-.97	-44.14
	II	.44	.09	-.20	.69	-.20	-.29	-.29	1.29	3.43	73.74	-.23	-12.80
	III	.36	.73	.16	.09	.16	.18	.18	.82	4.69	77.97	.22	12.53
	I+II			-.43	.01	-.43	-43.00	-43.00	44.00	13.65	85.81	-.98	-44.34
	I+II+III			-.24	.01	-.24	-35.00	-35.00	36.00	39.25	88.54	-.97	-44.19
2	W	.01	.03										
	I	.12	.36	-.33	.05	-1.00	-11.00	-19.80	12.00	6.19	80.82	-2.75	-70.02
	II	.22	.67	-.30	1.05	-.51	-.03	-.40	1.03	4.12	76.35	-.76	-37.15
	III	.20	.05	-.10	1.56	-.02	-.27	-.01	1.27	3.81	75.28	-.02	-1.36
	I+II			-.32	.03	-.75	-21.00	-29.80	22.00	17.24	86.68	-2.26	-66.11
	I+II+III			-.27	.02	-.51	-27.00	-30.20	28.00	32.60	88.25	-1.00	-60.91
3	W	.01	.06										
	I	.12	.73	-.67	.11	-1.67	-11.00	-15.00	12.00	2.18	65.33	-2.29	-66.43
	II	.22	1.33	-.61	1.70	-1.11	-.03	-.63	1.03	1.60	58.07	-.83	-39.81
	III	.24	1.45	-.12	2.09	-.14	-.09	-.05	1.09	2.14	64.93	-.10	-5.55
	I+II			-.64	.06	-1.39	-21.00	-25.00	22.00	7.67	82.57	-2.00	-64.36
	I+II+III			-.46	.04	-.97	-23.00	-26.27	24.00	18.10	86.84	-2.01	-63.51
4	W	.01	.12										
	I	.02	.24	-.12	.23	-1.79	-1.00	-7.70	2.00	6.03	80.59	-7.38	-82.28
	II	.04	.40	-.24	2.02	-1.35	-1.00	-.67	2.00	3.91	75.66	-2.79	-70.29
	III	.09	1.09	-.61	3.37	-.75	-1.25	-.22	2.25	2.29	66.45	-.69	-34.42
	I+II			-.18	.12	-1.57	-3.00	-13.52	4.00	20.34	87.18	-6.40	-81.23
	I+II+III			-.32	.08	-1.73	-8.00	-16.74	9.00	23.25	87.54	-3.56	-74.33
5	W	.01	.24										
	I	.01	.24	.00	.47	-1.79	.00	-3.77	1.00	6.03	80.59	-7.38	-82.28
	II	.01	.24	.00	2.26	-1.35	.00	-.60	1.00	7.02	82.72	-5.58	-79.85
	III	.01	.24	.00	3.62	-.75	.00	-.21	1.00	10.32	84.47	-3.06	-72.03
	I+II			.00	.24	-1.57	.00	-6.62	1.00	40.67	88.59	-12.96	-85.59
	I+II+III			.00	.16	-1.30	.00	-8.19	1.00	104.63	89.45	-16.04	-86.43
6	W	.01	.40										
	I	.01	.40	.00	.96	-1.79	.00	-1.86	1.00	3.02	71.66	-3.69	-74.83
	II	.01	.40	.00	2.75	-1.35	.00	-.49	1.00	3.91	75.66	-2.79	-70.29
	III	.01	.40	.00	4.10	-.75	.00	-.18	1.00	5.16	79.04	-1.54	-57.03
	I+II			.00	.40	-1.57	.00	-3.27	1.00	20.34	87.18	-6.40	-81.23
	I+II+III			.00	.32	-1.30	.00	-4.05	1.00	52.31	88.90	-8.02	-82.89
7	W	.01	.97										
	I	.01	.97	.00	1.93	-1.79	.00	-.93	1.00	1.51	56.45	-1.84	-61.53
	II	.01	.97	.00	3.72	-1.35	.00	-.36	1.00	1.96	62.92	-1.40	-54.30
	III	.01	.97	.00	5.07	-.75	.00	-.15	1.00	2.58	68.82	-.77	-37.63
	I+II			.00	.96	-1.57	.00	-1.63	1.00	10.17	84.38	-3.24	-72.85
	I+II+III			.00	.64	-1.30	.00	-2.02	1.00	26.16	87.81	-4.01	-76.00

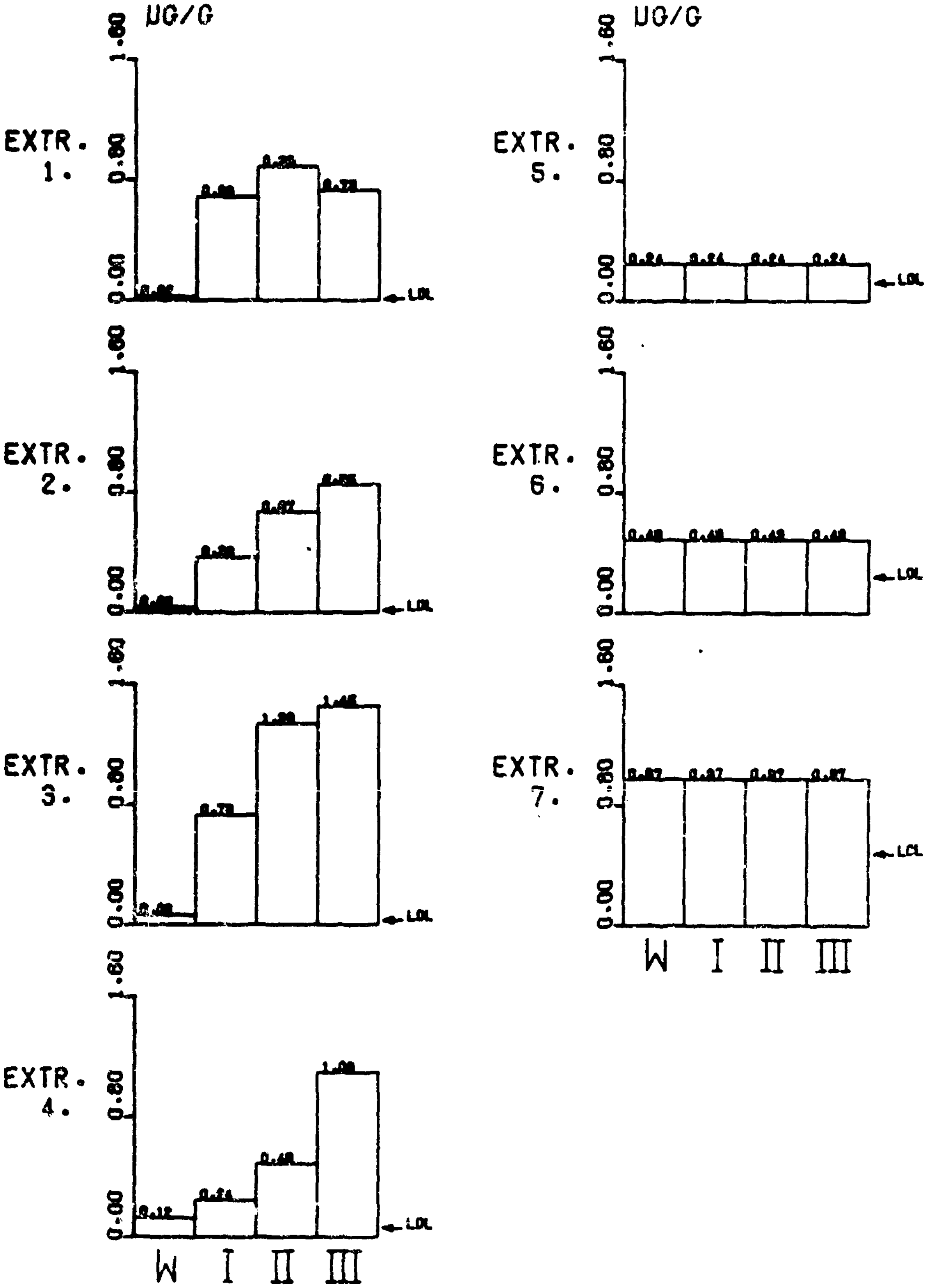


FIGURE 203. WEIGHT OF BERYLLIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

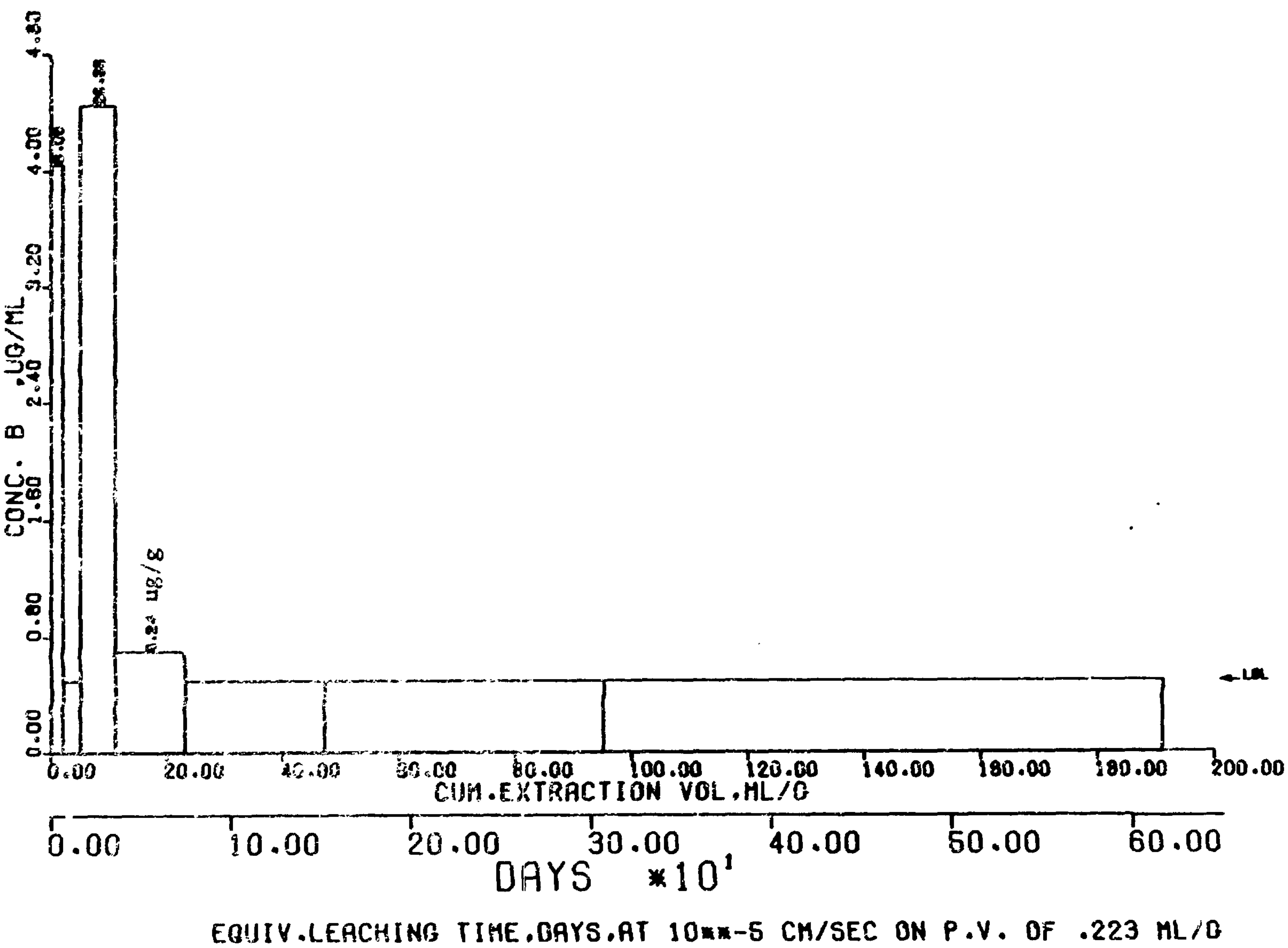


FIGURE 204. EXTRACTION OF BORON FROM OIL RE-REFINING WASTE (B).

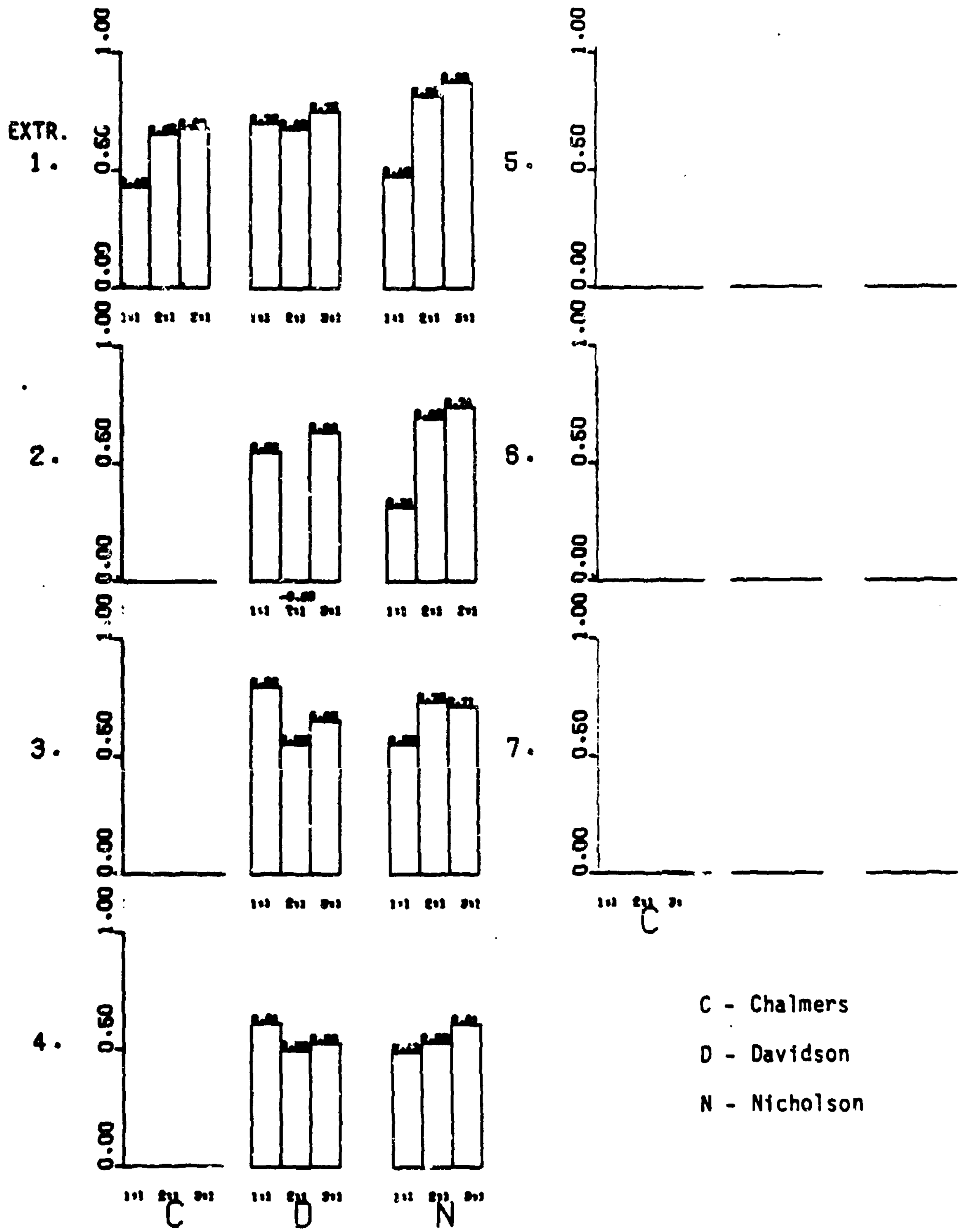


FIGURE 205. COMPARING FRACTION BORON RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 107. BORON FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.04	8.08										
	I	2.32	4.65	3.43	8.08	3.43	.43	.43	.58	4.51	77.49	.74	36.47
	II	1.41	2.83	1.82	4.65	1.82	.39	.39	.61	6.83	81.67	.64	32 74
	III	1.31	2.63	.20	2.83	.20	.07	.07	.93	6.74	81.56	.08	4.40
	I+II			2.63	4.04	2.63	.65	.65	.35	26.61	87.85	1.86	61.70
	I+II+III			1.82	2.69	1.82	.68	.68	.32	62.05	89.08	2.68	64.29
2	W	.50	1.50										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	4.44	26.66										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	.69	9.24										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	<.50	<12.12										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	<.50	<24.24										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	<.50	<48.48										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

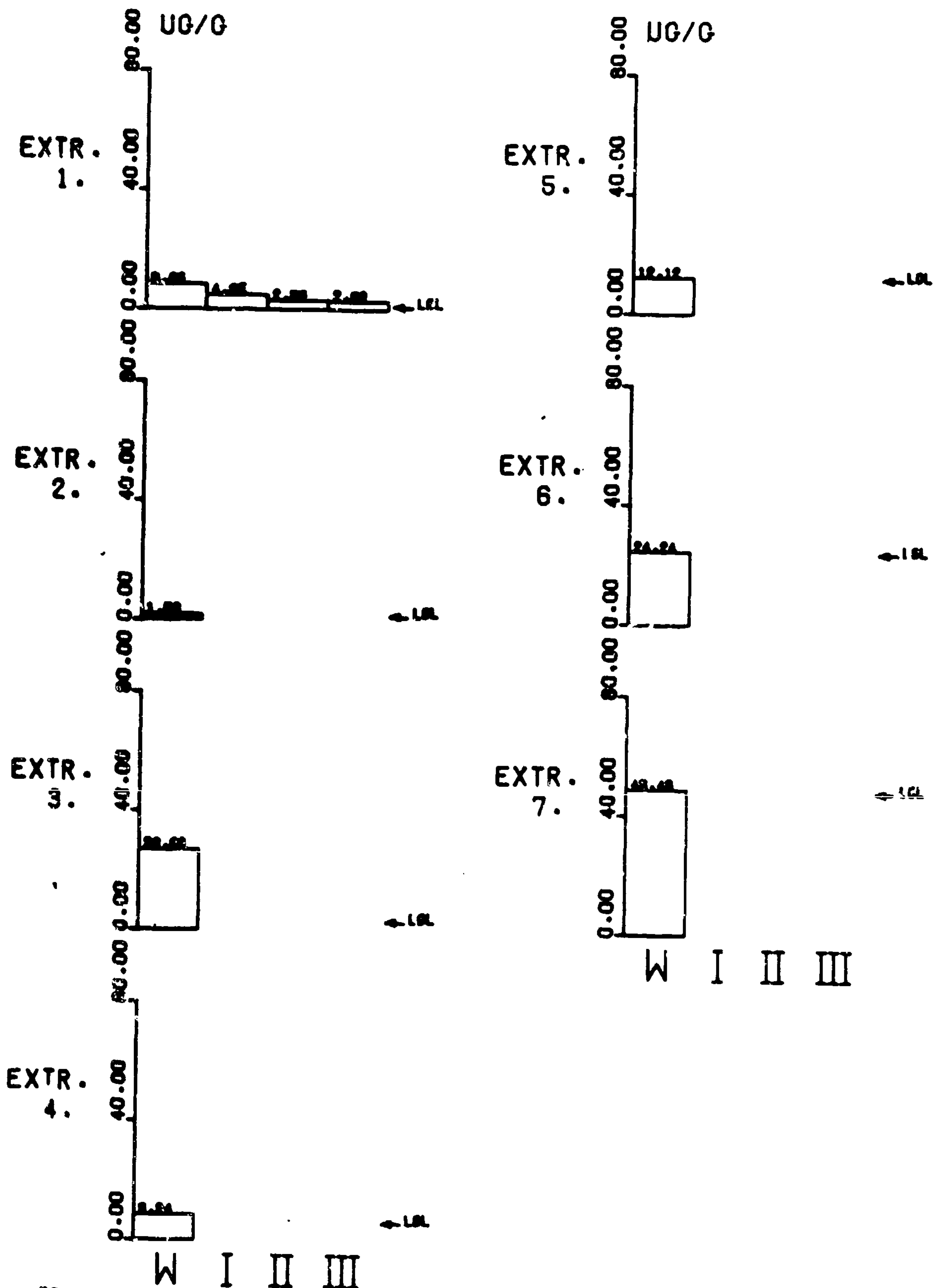


FIGURE 206. WEIGHT OF BORON FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 108. BORON FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.04	8.08										
	I	1.21	2.42	5.66	8.08	5.66	.70	.70	.30	13.84	85.87	2.33	66.80
	II	1.31	2.63	-.20	2.42	-.20	-.08	-.08	1.08	10.55	84.58	-.08	-4.40
	III	1.01	2.02	.61	2.63	.61	.23	.23	.77	14.11	85.95	.30	16.70
	I+II			2.73	4.04	2.73	.68	.68	.32	44.58	88.71	2.08	64.29
	I+II+III			2.02	2.69	2.02	.75	.75	.25	127.31	89.55	3.00	71.57
2	W	.50	1.50										
	I	.64	1.91	-.41	9.58	5.25	-.27	.55	1.27	17.36	86.70	2.75	70.01
	II	2.32	6.97	-5.06	4.33	-5.26	-2.65	-1.21	3.65	3.25	72.89	-.76	-37.06
	III	.50	1.52	5.45	9.59	6.06	.78	.63	.22	22.42	87.45	4.00	75.96
	I+II			-2.73	4.79	-.01	-3.65	-.00	4.65	16.01	86.43	-.00	-.12
	I+II+III			-.01	3.19	2.01	-.01	.63	1.01	169.73	89.66	3.99	75.93
3	W	4.44	26.66										
	I	.50	3.03	23.63	36.24	28.86	.89	.80	.11	18.74	86.95	9.53	84.01
	II	1.11	6.67	-3.64	7.36	-0.90	-1.22	-1.21	2.20	2.85	70.67	-1.33	-53.16
	III	1.52	9.09	-2.42	16.26	3.64	-.36	.22	1.36	3.47	73.92	.40	21.80
	I+II			10.00	18.12	9.99	.75	.55	.25	19.74	87.10	3.00	71.55
	I+II+III			5.06	12.00	7.07	.66	.65	.34	30.22	88.10	2.60	68.95
4	W	.69	8.24										
	I	.84	10.06	-1.82	44.49	27.66	-.22	.61	1.22	5.46	79.63	2.69	69.61
	II	.52	6.18	3.88	17.42	-5.02	.39	-.29	.61	3.70	74.88	-.81	-39.08
	III	.71	8.48	-2.30	22.44	1.33	-.37	.06	1.37	3.45	73.82	.16	8.93
	I+II			1.83	22.24	11.32	.25	.50	.75	21.62	87.35	3.57	74.34
	I+II+III			-.08	14.83	7.79	-.03	.53	1.03	32.35	88.23	2.76	70.05
5	W	(.50	(12.12										
	I	(.50	(12.12										
	II	(.50	(12.12										
	III	(.50	(12.12										
	I+II												
	I+II+III												
6	W	(.50	(24.24										
	I	(.50	(24.24										
	II	(.50	(24.24										
	III	(.50	(24.24										
	I+II												
	I+II+III												
7	W	(.50	(48.48										
	I	(.50	(48.48										
	II	(.50	(48.48										
	III	(.50	(48.48										
	I+II												
	I+II+III												

The remainder of the table was not calculated because the concentrations were below the detection limit.

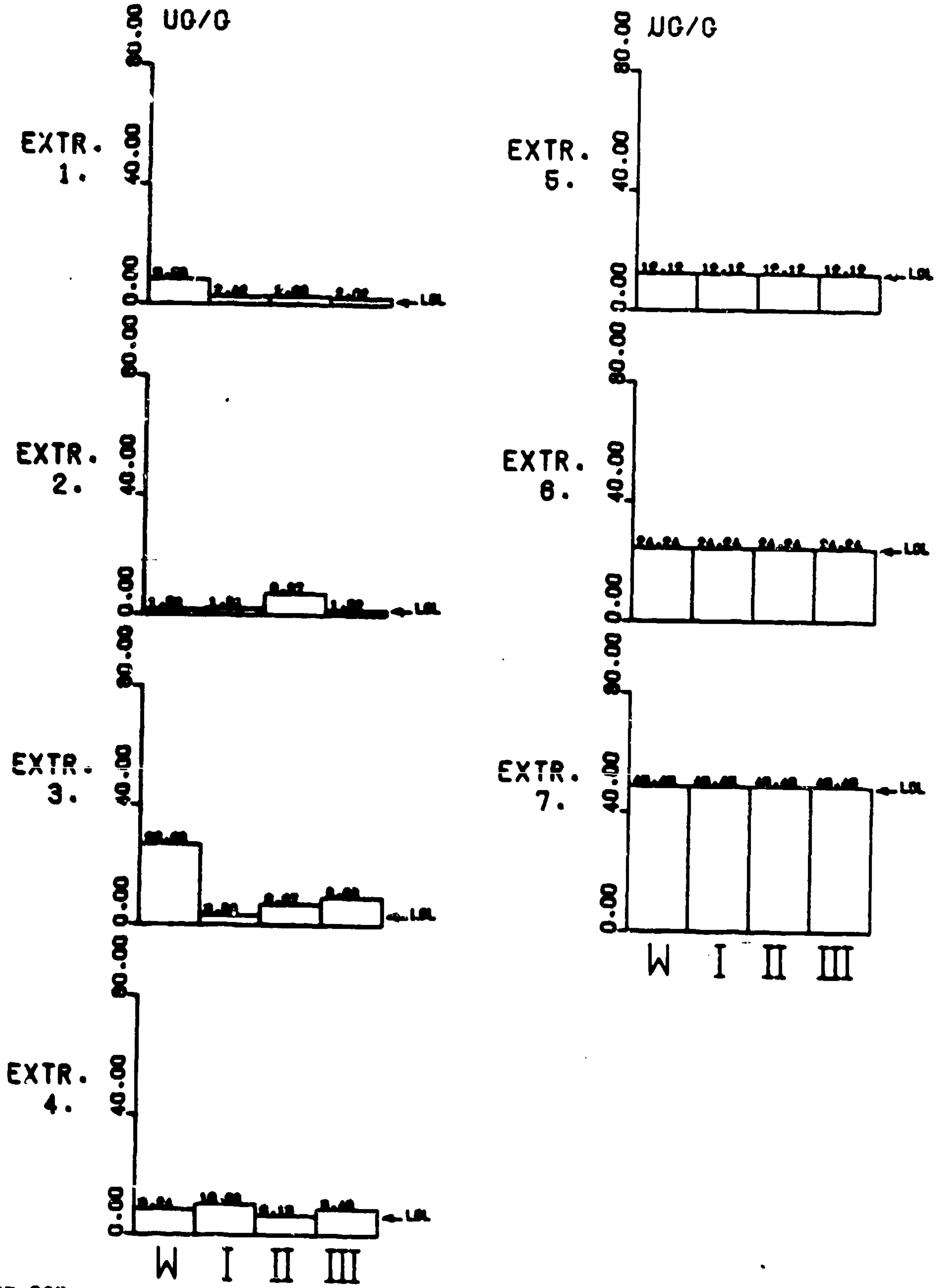


FIGURE 207. WEIGHT OF BORON FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 109. BORON FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	4.04	8.08										
	I	2.12	4.24	3.84	8.08	3.84	.48	.48	.52	5.36	79.43	.90	42.14
	II	.74	1.47	2.77	4.24	2.77	.65	.65	.35	14.69	86.11	1.88	61.95
	III	.50	1.00	.47	1.47	.47	.32	.32	.68	19.37	87.05	.47	25.39
	I+II			3.30	4.04	3.30	.82	.82	.18	55.75	88.97	4.48	77.42
	I+II+III			2.36	2.69	2.36	.88	.88	.12	177.18	89.68	7.08	81.96
2	W	.50	1.50										
	I	.78	2.33	-.83	9.58	3.00	-.56	.31	1.56	9.39	83.92	1.29	52.17
	II	.50	1.50	.83	6.58	3.60	.36	.55	.64	15.00	86.19	2.40	67.38
	III	.50	1.50	.00	2.97	.47	.00	.16	1.00	12.92	85.57	.32	17.56
	I+II			.00	4.79	3.30	.00	.69	1.00	54.00	88.95	4.40	77.21
	I+II+III			.00	3.19	2.36	.00	.74	1.00	118.12	89.51	4.72	78.04
3	W	4.44	26.66										
	I	1.62	9.70	16.97	36.24	19.97	.64	.55	.36	4.01	75.99	2.06	64.11
	II	1.11	6.67	3.03	16.27	6.63	.31	.41	.69	3.83	75.37	.99	44.85
	III	1.31	7.86	-1.21	9.64	-.74	-.18	-.08	1.18	2.31	66.55	-.09	-5.35
	I+II			10.00	18.12	13.30	.75	.73	.25	15.33	86.27	3.99	75.93
	I+II+III			6.26	12.00	8.62	.70	.71	.30	24.00	87.70	3.28	73.06
4	W	.69	8.24										
	I	.55	6.54	1.70	14.49	21.67	.21	.49	.79	6.20	80.84	3.31	73.19
	II	.94	11.27	-4.73	2.92	1.90	-.72	.08	1.72	1.85	61.55	.17	9.59
	III	.60	7.15	4.12	20.91	3.38	.37	.16	.63	3.12	72.21	.47	25.32
	I+II			-1.52	22.24	11.79	-.37	.53	1.37	8.80	83.52	2.09	64.45
	I+II+III			.36	14.83	8.99	.13	.61	.87	27.56	87.92	3.77	75.14
5	W	< .50	<12.12										
	I	< .50	<12.12										
	II	< .50	<12.12										
	III	< .50	<12.12										
	I+II												
	I+II+III												
6	W	< .50	<24.24										
	I	< .50	<24.24										
	II	< .50	<24.24										
	III	< .50	<24.24										
	I+II												
	I+II+III												
7	W	< .50	<48.48										
	I	< .50	<48.48										
	II	< .50	<48.48										
	III	< .50	<48.48										
	I+II												
	I+II+III												

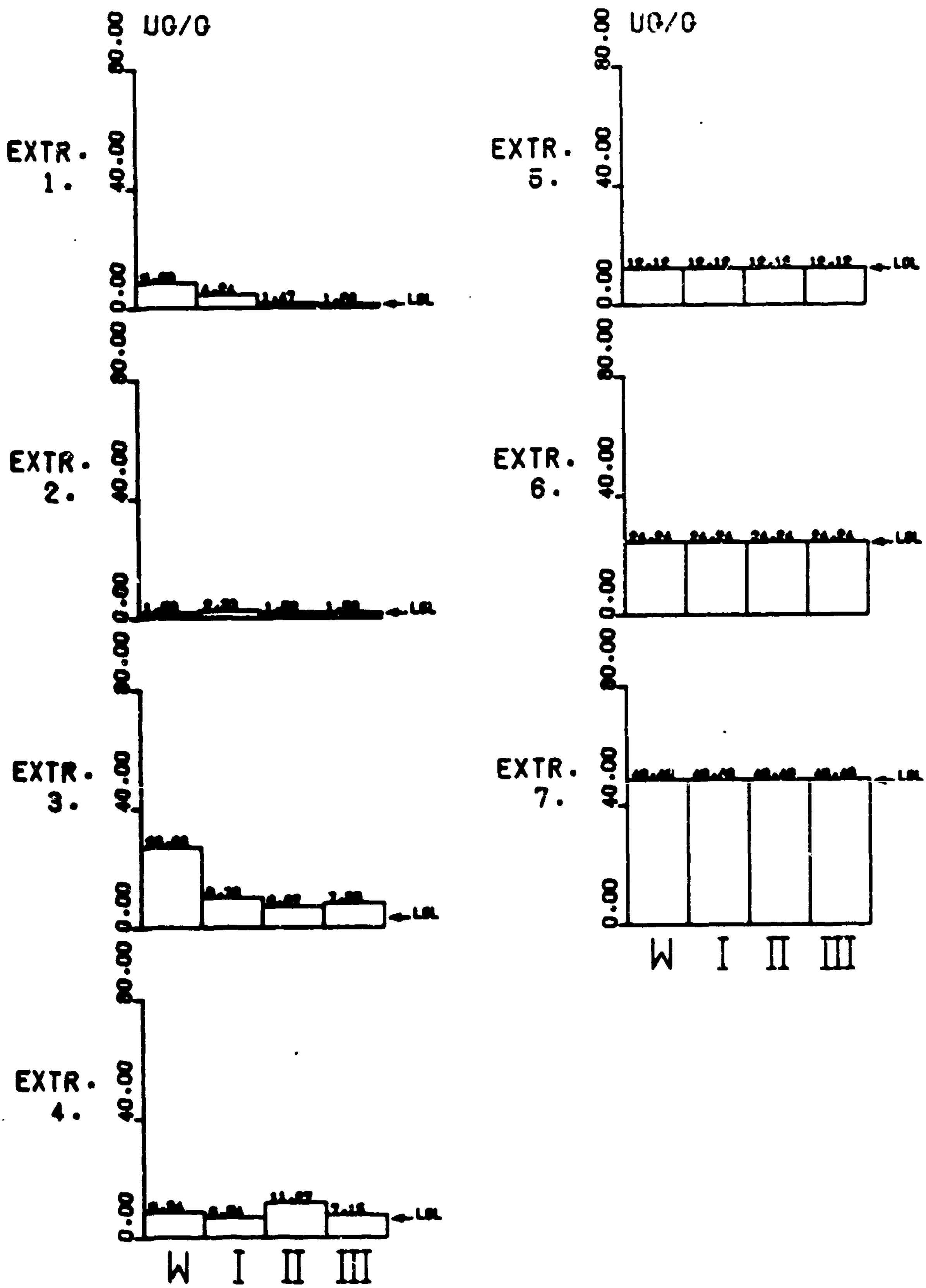


FIGURE 208. WEIGHT OF BORON FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

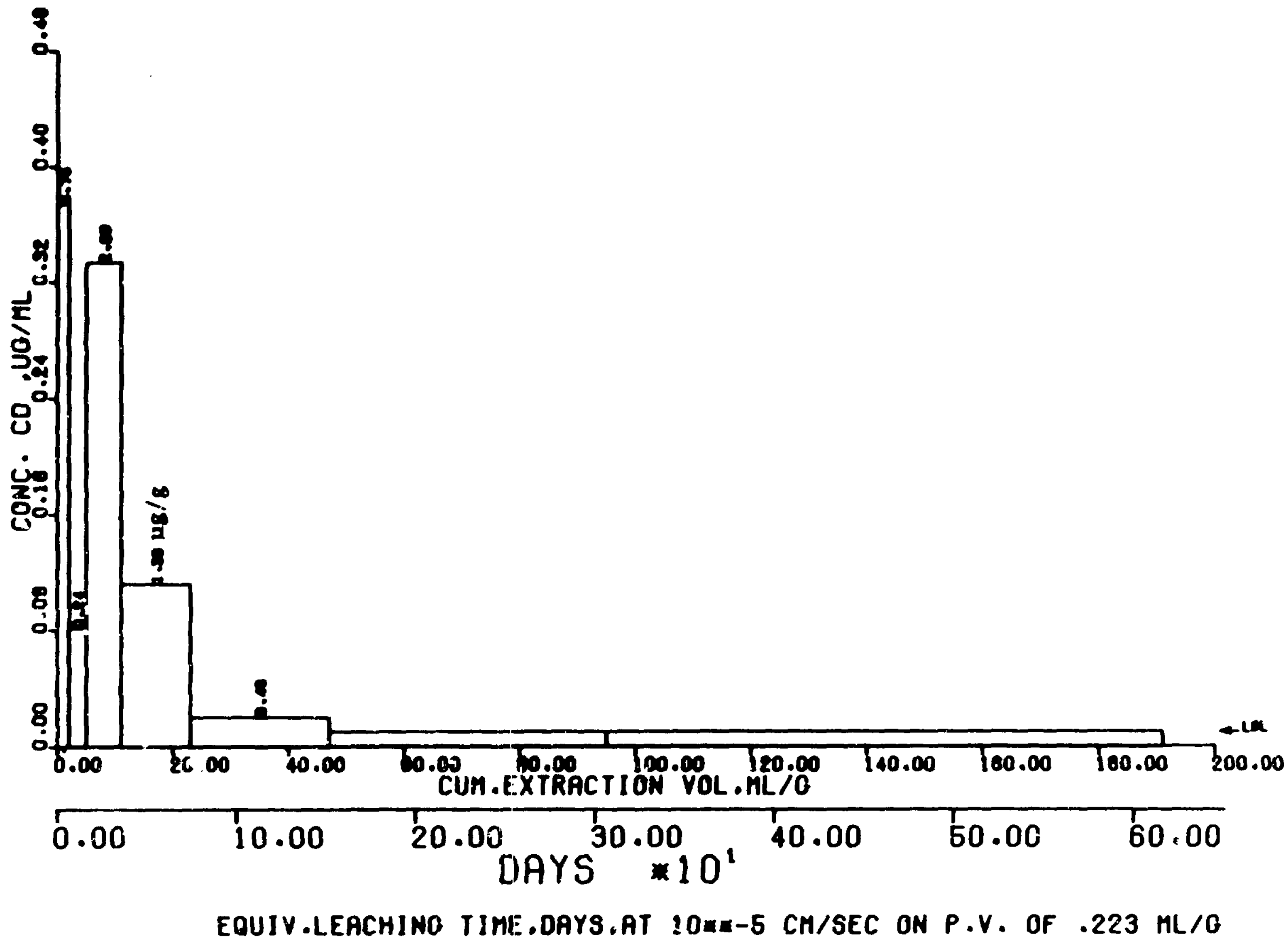
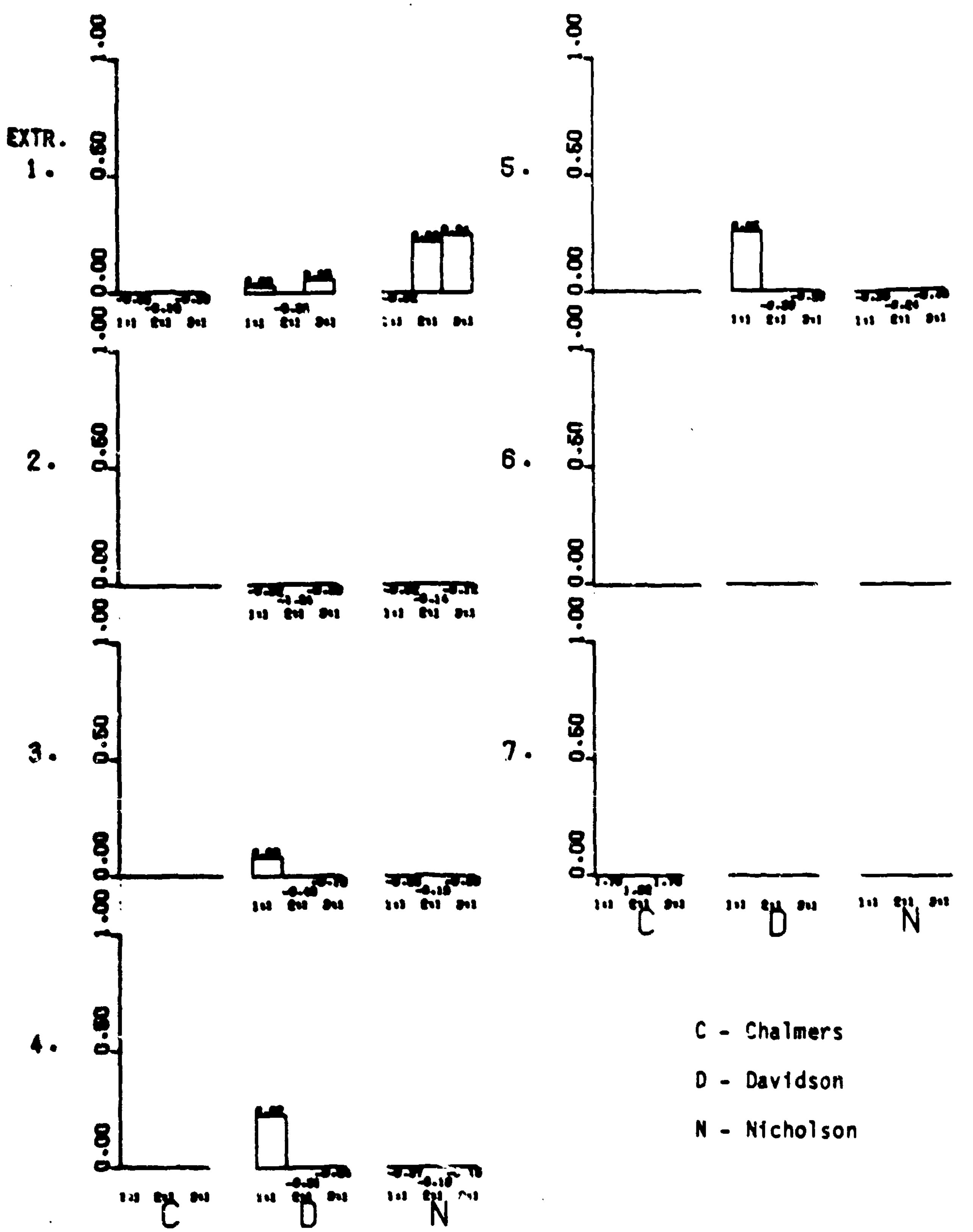


FIGURE 209. EXTRACTION OF CADMIUM FROM OIL RE-REFINING WASTE (B).



C - Chalmers

D - Davidson

N - Nicholson

FIGURE 210. COMPARING FRACTION CADMIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 110. CADMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.37	.75										
	I	.62	1.23	-.48	.75	-.48	-.65	-.65	1.65	.01	.71	-.39	-21.40
	II	.44	.89	.34	1.23	.34	.28	.28	.72	.95	43.58	.39	21.12
	III	.52	1.03	-.14	.89	-.14	-.16	-.16	1.16	.35	19.19	-.14	-7.82
	I+II			-.07	.37	-.07	-.19	-.19	1.19	2.09	64.44	-.16	-9.08
	I+II+III			-.09	.25	-.09	-.38	-.38	1.38	4.09	76.27	-.27	-15.35
2	W	.08	.24										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	.33	2.00										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	.11	1.33										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	.02	.40										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	.01	.40										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	.01	.77										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

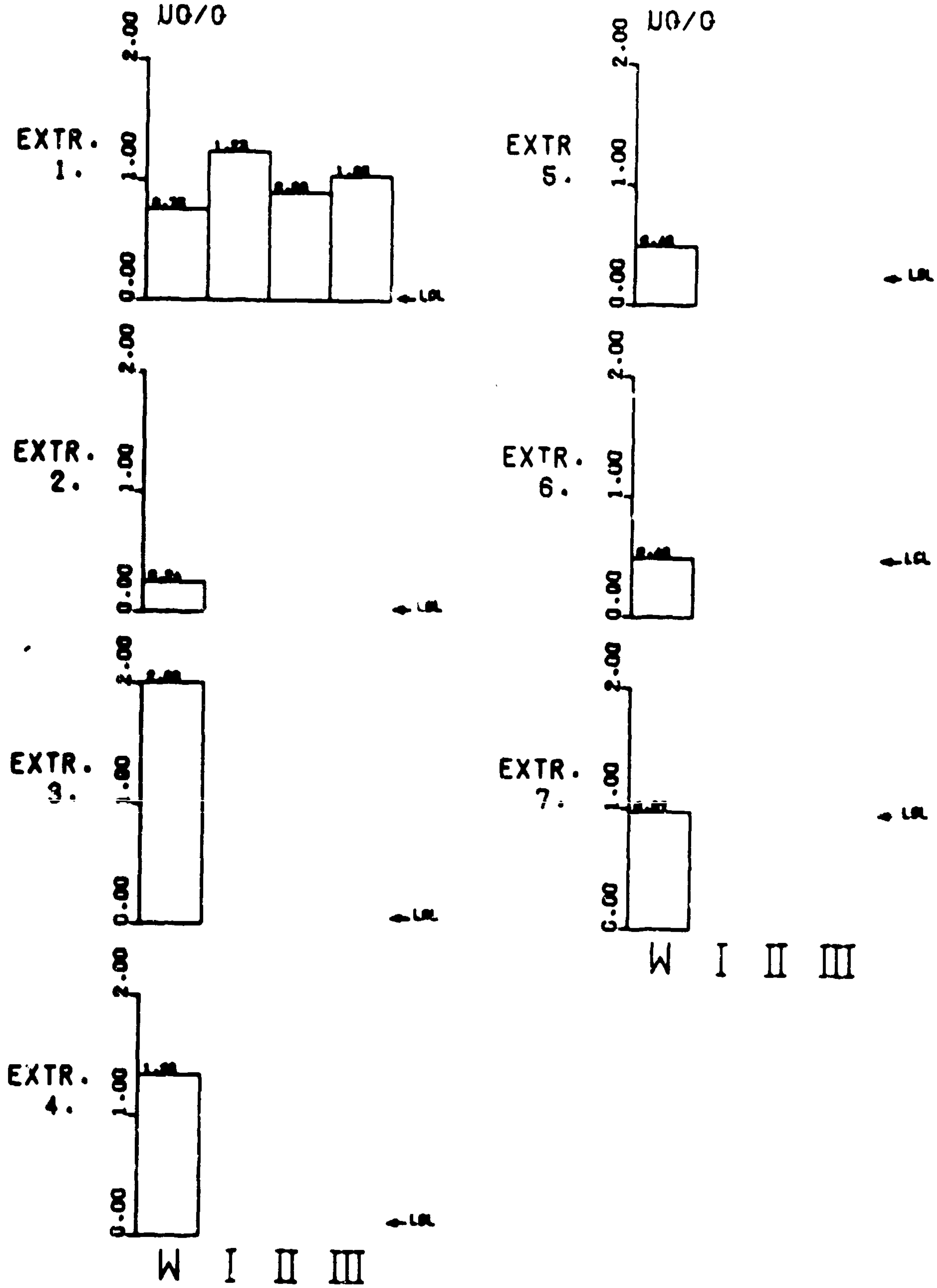


FIGURE 211. WEIGHT OF CADMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 111. CADMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.37	.75										
	I	.36	.73	.02	.75	.02	.03	.03	.97	2.02	63.68	.03	1.59
	II	.50	1.01	-.28	.73	-.28	-.39	-.39	1.39	1.16	49.13	-.28	-15.64
	III	.35	.71	.30	1.01	.30	.30	.30	.70	2.48	68.04	.43	23.20
	I+II			-.13	.37	-.13	-.35	-.35	1.35	5.48	79.66	-.26	-14.57
	I+II+III			.01	.25	.01	.05	.05	.95	18.52	86.91	.06	3.27
2	W	.08	.24										
	I	.19	.58	-.33	.99	-.31	-1.37	-.32	2.38	1.77	63.14	-.54	-28.54
	II	.40	1.21	-.64	1.30	-.92	-1.11	-.71	2.11	.44	23.66	-.76	-37.17
	III	.19	.58	.64	2.22	.94	.52	.42	.47	4.15	76.45	1.63	58.50
	I+II			-.40	.49	-.62	-4.00	-1.24	5.00	3.77	75.14	-1.02	-45.47
	I+II+III			-.11	.33	-.10	-1.37	-.30	2.38	22.16	87.42	-.51	-26.97
3	W	.33	2.00										
	I	.24	1.45	.55	2.99	.23	.27	.08	.73	1.16	49.16	.16	9.07
	II	.37	2.24	-.79	2.76	-1.71	-.54	-.62	1.54	-.11	-6.54	-.76	-37.20
	III	.37	2.24	.00	4.46	.94	.00	.21	1.00	1.07	46.82	.42	22.73
	I+II			-.12	1.49	-.74	-.12	-.49	1.12	1.93	62.60	-.66	-33.33
	I+II+III			-.00	1.00	-.10	-.12	-.10	1.12	5.58	79.84	-.24	-13.43
4	W	.11	1.33										
	I	.05	.61	.73	4.32	.96	.55	.22	.45	3.98	75.80	1.58	57.72
	II	.10	1.21	-.61	3.36	-2.31	-1.00	-.69	2.00	-.71	-35.45	-1.91	-62.34
	III	.15	1.82	-.61	5.68	.33	-.50	.06	1.50	.78	44.45	.18	10.39
	I+II			.06	2.16	-.60	.09	-.31	.91	3.67	74.75	-1.12	-48.15
	I+II+III			-.16	1.44	-.34	-.36	-.24	1.36	6.62	81.41	-.56	-29.30
5	W	.02	.40										
	I	<.01	<.24	.24	4.01	1.20	.50	.25	.50	10.94	84.78	4.96	78.60
	II	.03	.73	-.40	3.61	-2.80	-2.00	-.78	3.00	-1.85	-61.65	-3.85	-75.43
	III	.03	.73	.00	6.40	.33	.00	.05	1.00	2.45	67.82	.46	24.62
	I+II			-.12	2.40	-.80	-.50	-.33	1.50	5.78	80.19	-2.19	-65.50
	I+II+III			-.00	1.60	-.42	-.50	-.26	1.50	16.21	86.47	-1.74	-60.06
6	W	<.01	<.48										
	I	.05	2.42										
	II	.04	1.94										
	III	.02	.97										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the occurrence of values below the detection limit.

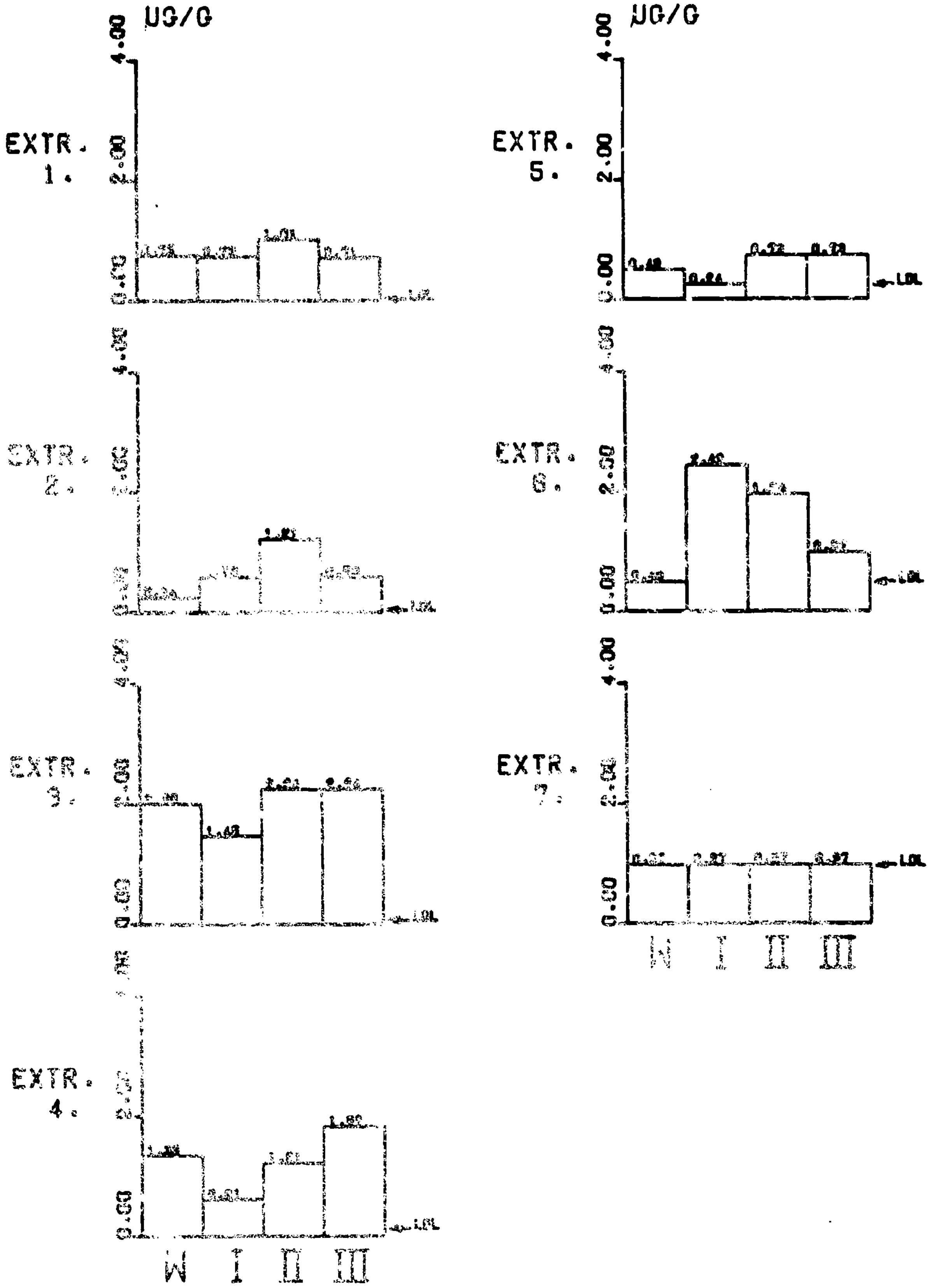


FIGURE 212. WEIGHT OF CADMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 112. CADMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.37	.75										
	I	.61	1.21	-.46	.75	-.46	-.62	-.62	1.62	.03	1.67	-.38	-20.97
	II	.29	.59	.63	1.21	.63	.52	.52	.48	1.92	62.52	1.07	46.91
	III	.28	.57	.02	.59	.02	.03	.03	.97	.92	42.61	.04	2.05
	I+II			.08	.37	.08	.22	.22	.78	3.69	74.84	.28	15.42
	I+II+III			.06	.25	.06	.24	.24	.76	8.26	83.11	.32	17.82
2	W	.08	.24										
	I	.13	.39	-.15	.99	-.62	-.63	-.62	1.63	-.29	-16.42	-1.56	-57.41
	II	.18	.55	-.15	1.61	.47	-.30	.30	1.30	1.79	60.77	.07	41.04
	III	.18	.55	.00	1.13	.02	.06	.02	1.00	.95	43.65	.04	2.12
	I+II			-.15	.49	-.07	-1.25	-.14	2.25	3.41	73.65	-.26	-14.53
	I+II+III			-.10	.33	-.04	-1.25	-.12	2.25	8.03	82.90	-.22	-12.53
3	W	.33	2.06										
	I	.56	3.33	-1.33	2.99	-1.95	-.67	-.65	1.67	-.43	-23.58	-.58	-30.32
	II	.40	2.42	.91	4.94	1.38	.27	.28	.73	.78	37.85	.57	29.72
	III	.34	2.06	.36	3.56	.38	.15	.11	.85	.43	23.22	.19	10.55
	I+II			-.31	1.49	-.28	-.21	-.19	1.21	.59	30.61	-.23	-13.13
	I+II+III			-.02	1.06	-.06	-.03	-.04	1.03	2.10	64.49	-.09	-5.04
4	W	.11	1.33										
	I	.08	.97	.36	4.32	-1.59	.27	-.37	.73	-1.12	-48.23	-1.64	-58.56
	II	.10	1.21	-.24	5.91	1.14	-.25	.19	1.25	1.35	53.56	.94	43.28
	III	.15	1.82	-.61	4.77	-.22	-.50	-.05	1.50	.15	8.69	-.12	-6.97
	I+II			.06	2.16	-.22	.09	-.10	.91	1.28	52.08	-.37	-20.14
	I+II+III			-.16	1.44	-.22	-.36	-.15	1.36	2.11	64.63	-.37	-20.14
5	W	.02	.48										
	I	.02	.48	.00	4.01	-1.59	.00	-.33	1.00	-2.24	-65.94	-3.27	-73.00
	II	.05	1.21	-.73	6.39	.41	-1.50	.06	2.50	.75	37.02	.34	18.86
	III	.09	2.18	-.97	5.90	-1.19	-.80	-.20	1.80	-.32	-17.59	-.55	-28.65
	I+II			-.36	2.40	-.59	-1.50	-.24	2.50	.68	34.35	-.97	-44.03
	I+II+III			-.57	1.60	-.79	-3.50	-.49	4.50	.98	44.40	-1.08	-47.29
6	W	<.01	< .48										
	I	<.01	< .43										
	II	.04	1.94										
	III	<.01	< .48										
	I+II												
	I+II+III												
7	W	<.01	< .97										
	I	<.01	< .97										
	II	<.01	< .97										
	III	<.01	< .97										
	I+II												
	I+II+III												

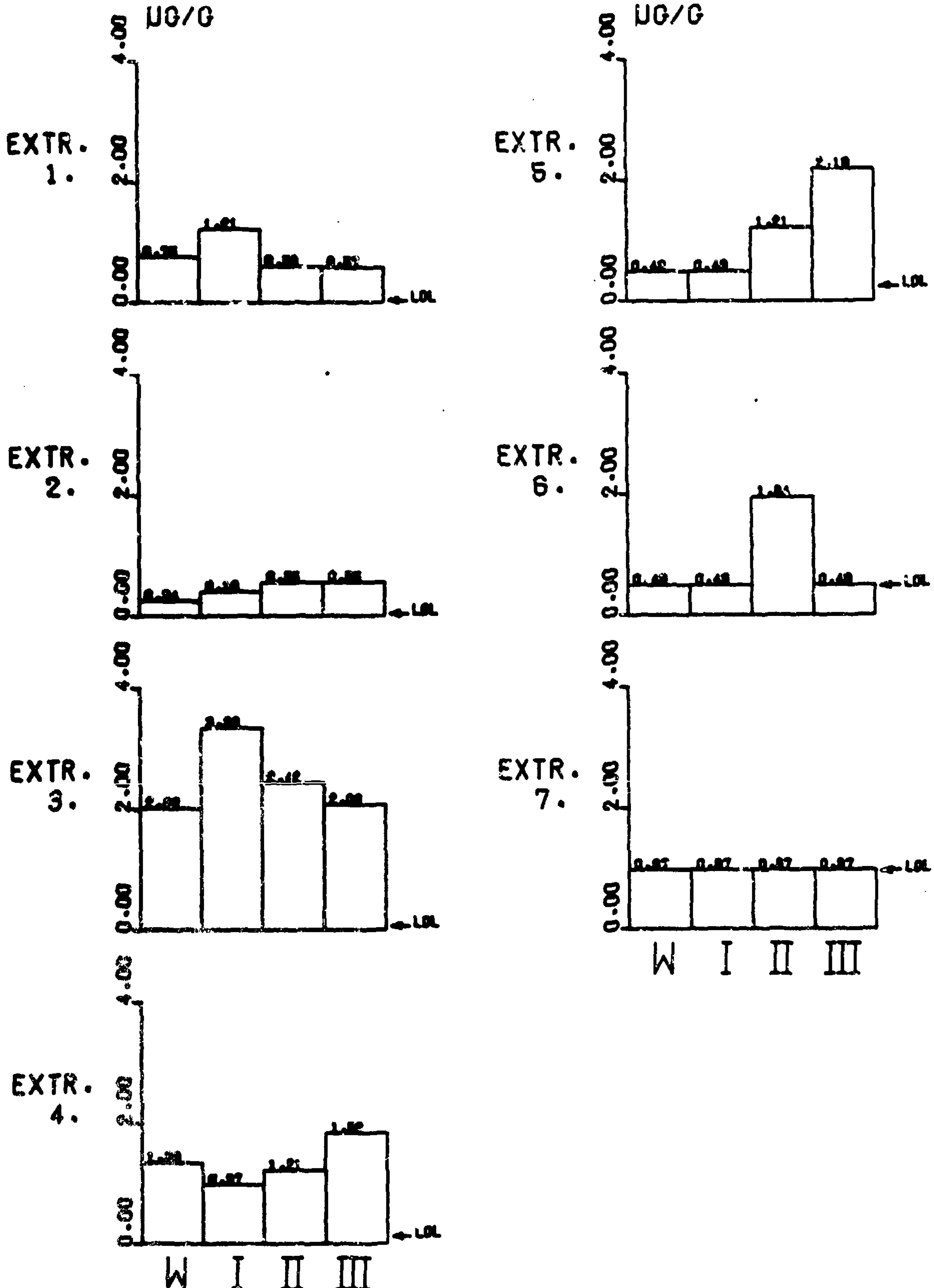


FIGURE 213. WEIGHT OF CADMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

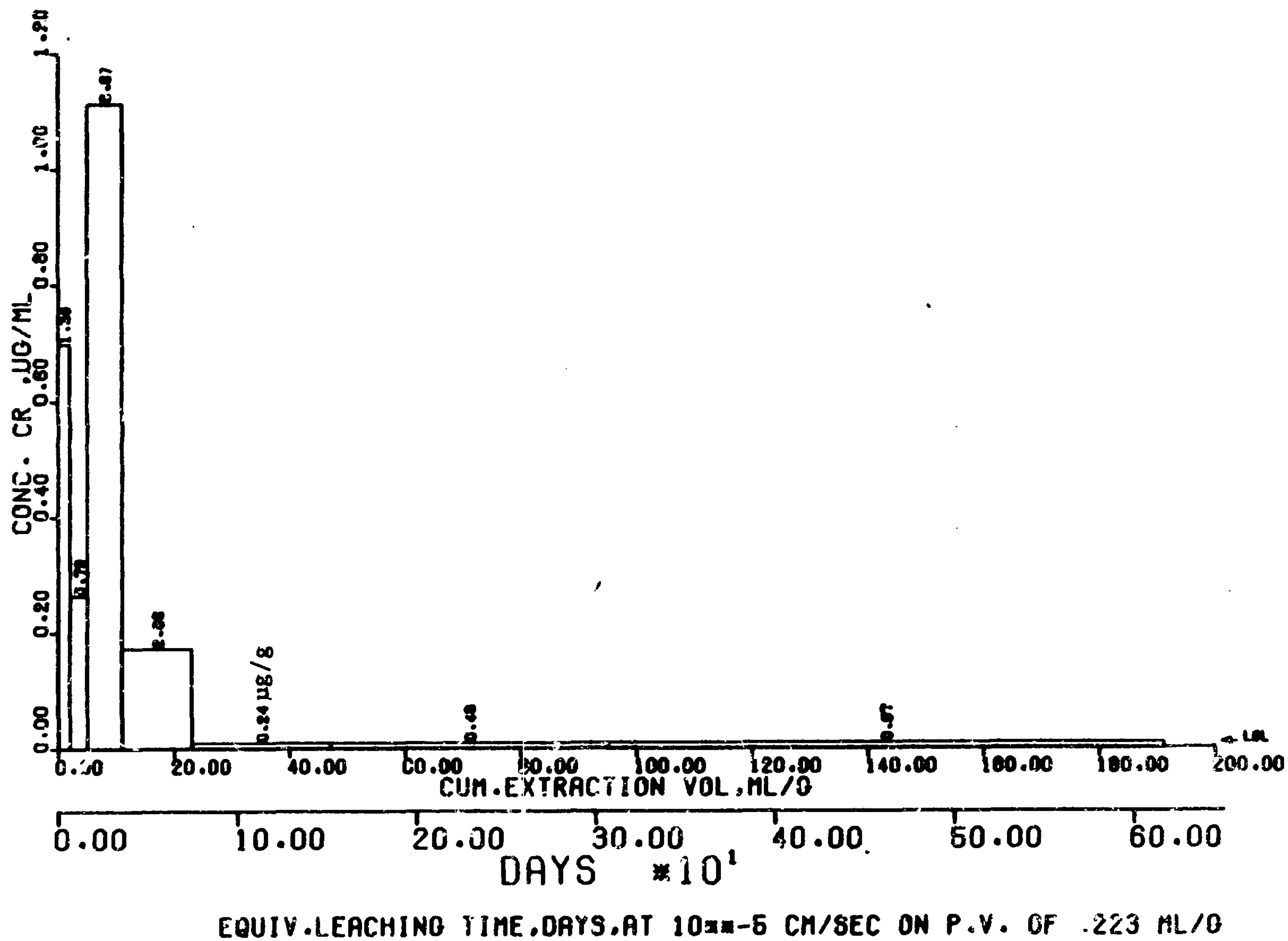


FIGURE 214. EXTRACTION OF CHROMIUM FROM OIL RE-REFINING WASTE (B).

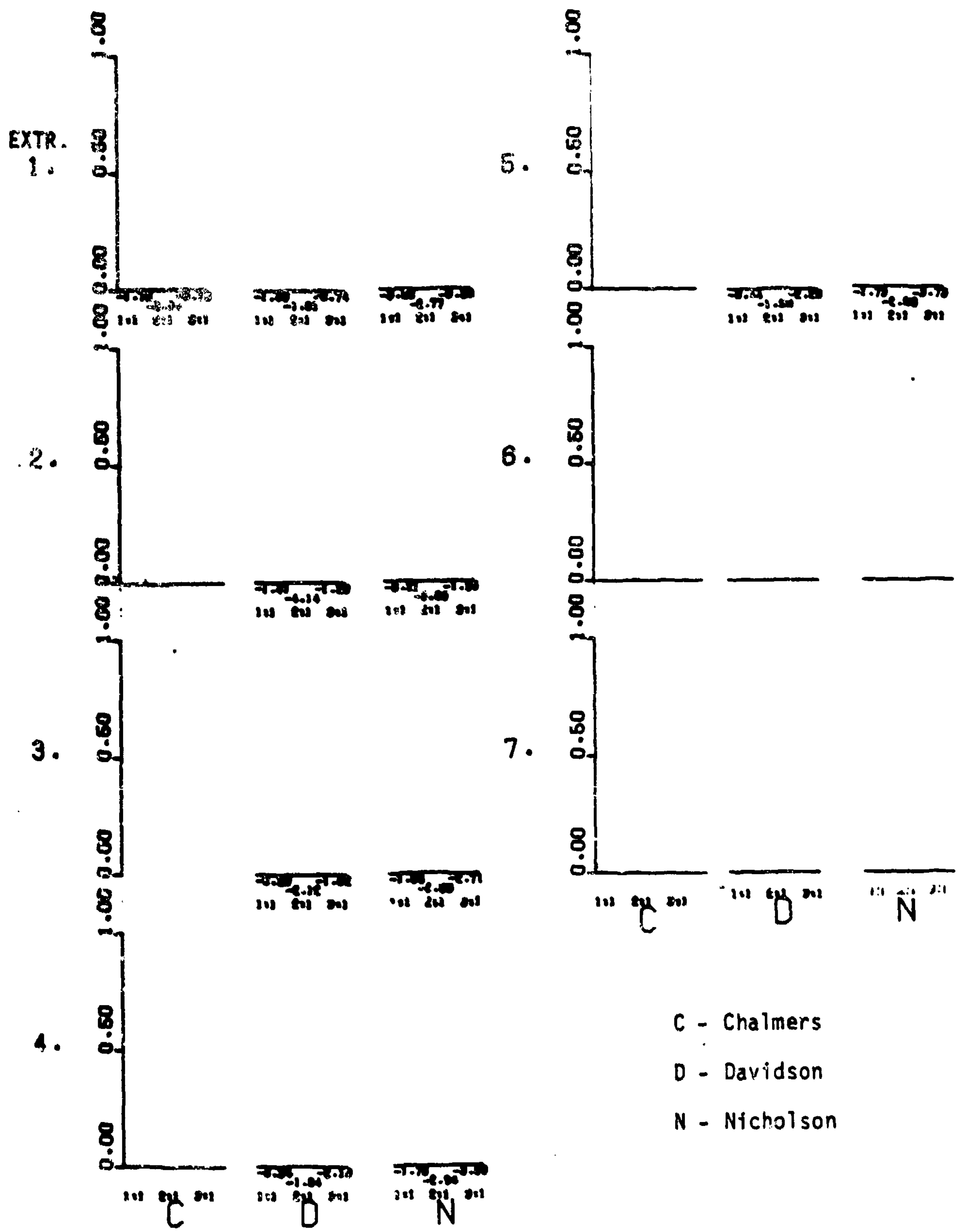


FIGURE 215. COMPARING FRACTION CHROMIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 113. CHROMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	ANT.PENETR. UG/ML	ANT.PENETR. UG/G	ANT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.70	1.39										
	I	1.92	3.84	-2.44	1.39	-2.44	-1.75	-1.75	2.75	6.66	81.46	-.64	-32.49
	II	3.23	6.46	-2.63	3.84	-2.63	-.68	-.68	1.68	3.73	75.71	-.41	-22.11
	III	.81	1.62	4.05	6.46	4.05	.75	.75	.25	20.33	87.18	3.00	71.57
	I+II			-2.54	.70	-2.54	-3.64	-3.64	4.64	16.54	86.54	-.78	-38.11
	I+II+III			-.07	.46	-.07	-.16	-.16	1.16	155.80	89.63	-.14	-7.83
2	W	.26	.79										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	1.11	6.67										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	.17	2.06										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	.01	.24										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	.01	.40										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	.01	.97										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

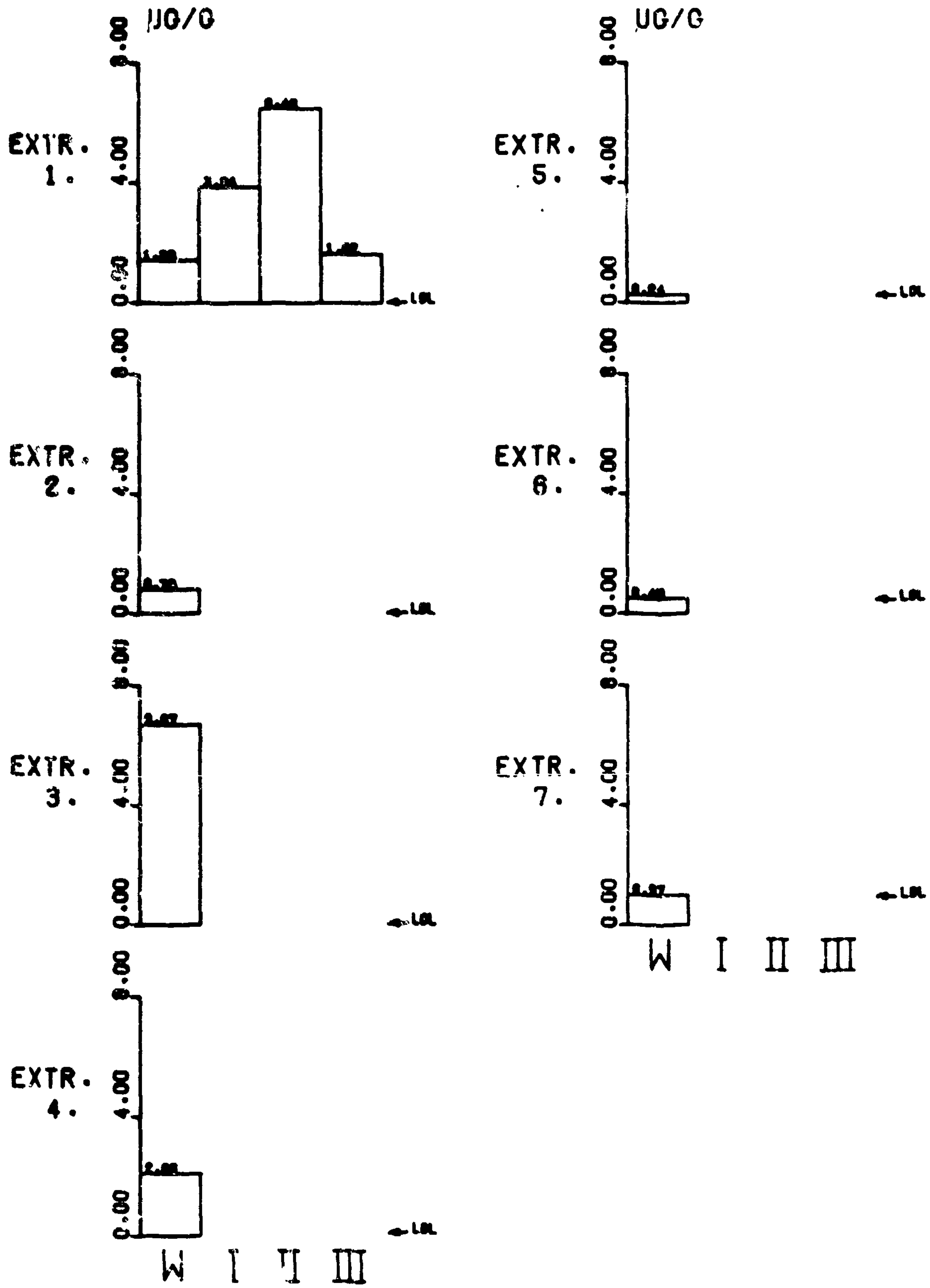


FIGURE 216. WEIGHT OF CHROMIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 114. CHROMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.70	1.39										
	I	1.72	3.43	-2.04	1.39	-2.04	-1.46	-1.46	2.46	10.65	84.63	-.59	-30.72
	II	1.82	3.64	-.20	3.43	-.20	-.06	-.06	1.06	10.56	84.59	-.06	-3.18
	III	1.21	2.42	1.21	3.64	1.21	.33	.33	.67	16.42	86.52	.50	26.57
	I+II			-1.12	.70	-1.12	-1.61	-1.61	2.61	41.85	88.63	-.62	-31.66
	I+II+III			-.34	.46	-.34	-.74	-.74	1.74	142.89	87.60	-.43	-23.03
2	W	.26	.79										
	I	.61	1.82	-1.63	2.18	-3.07	-1.31	-1.41	2.31	19.54	87.07	-1.69	-59.37
	II	2.53	7.58	-5.76	5.25	-5.96	-3.17	-1.13	4.17	4.31	76.93	-.79	-38.19
	III	.85	2.55	5.03	11.21	6.24	.66	.56	.34	17.62	86.75	2.45	67.82
	I+II			-3.39	1.09	-4.51	-8.62	-4.14	9.62	19.19	87.02	-1.19	-50.01
	I+II+III			-.59	.73	-.93	-2.23	-1.28	3.23	135.40	89.58	-1.18	-47.60
3	W	1.11	6.67										
	I	1.01	6.06	.01	8.05	-2.46	.09	-.28	.91	5.96	80.48	-.41	-22.13
	II	2.73	16.36	-10.30	11.31	-16.26	-1.70	-1.44	2.70	1.37	53.78	-.99	-44.82
	III	3.03	18.18	-1.82	27.57	4.42	-.11	.16	1.11	2.37	67.09	.24	13.68
	I+II			-4.05	4.42	-9.36	-1.45	-2.12	2.45	8.29	83.12	-1.14	-48.75
	I+II+III			-3.04	2.95	-4.77	-1.73	-1.62	2.73	18.32	86.88	-.79	-38.19
4	W	.17	2.04										
	I	.27	3.27	-1.21	18.91	-3.68	-.59	-.34	1.59	10.67	84.65	-1.12	-48.33
	II	.37	4.48	-1.21	14.58	-17.47	-.37	-1.20	1.37	4.71	78.02	-3.90	-75.61
	III	.96	11.51	-7.03	32.06	-2.61	-1.57	-.08	2.57	3.13	72.26	-.23	-12.75
	I+II			-1.21	5.45	-10.57	-1.10	-1.94	2.10	29.71	88.07	-4.72	-76.03
	I+II+III			-3.15	3.64	-7.92	-4.59	-2.18	5.59	28.11	87.96	-2.06	-64.14
5	W	.01	.24										
	I	.06	1.45	-1.21	11.15	-4.09	-5.00	-.44	6.00	23.18	87.53	-3.36	-73.43
	II	<.01	<.24	1.21	16.04	-16.26	.83	-1.01	.17	92.16	89.38	-67.06	-89.15
	III	.07	1.70	-1.45	32.30	-4.06	-6.00	-.13	7.00	20.36	87.19	-2.37	-67.32
	I+II			.00	5.50	-10.57	.00	-1.90	1.00	549.71	89.90	-87.25	-89.3
	I+II+III			-.40	3.72	-8.40	-6.00	-2.26	7.00	189.80	89.70	-14.86	-86.15
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.97										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

The remainder of the table was not calculated because the concentrations were below the detection limit.

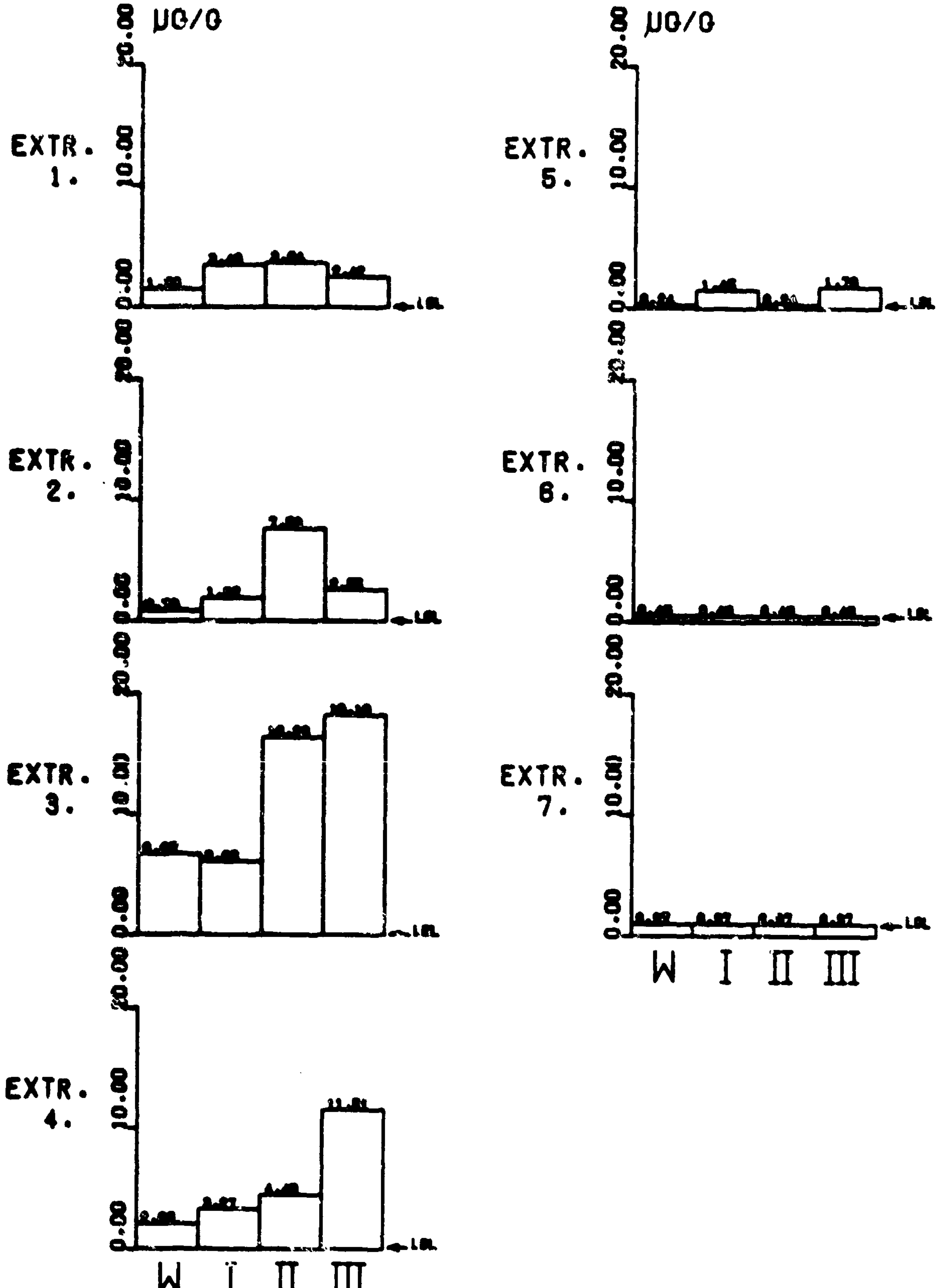


FIGURE 217. WEIGHT OF CHROMIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 115. CHROMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.70	1.39										
	I	2.93	5.06	-4.46	1.39	-4.46	-3.20	-3.20	4.20	4.07	78.40	-.76	-37.31
	II	2.63	5.25	.61	5.06	.61	.10	.10	.90	6.40	81.12	.12	6.58
	III	1.11	2.22	3.03	5.25	3.03	.58	.58	.42	16.22	86.47	1.36	53.75
	I+II			-1.93	.70	-1.93	-2.77	-2.77	3.77	24.40	87.65	-.73	-36.30
	I+II+III			-.20	.46	-.20	-.59	-.59	1.59	133.29	89.57	-.37	-20.44
2	W	.26	.79										
	I	1.11	3.33	-2.55	2.18	-7.01	-3.23	-3.21	4.23	7.90	82.69	-2.10	-64.57
	II	1.62	4.85	[illegible]	9.19	-.71	-.45	-.10	1.45	6.62	81.41	-.19	-10.62
	III	1.11	3.33	1.51	10.10	4.55	.31	.45	.69	11.26	84.93	1.36	53.75
	I+II			-2.03	1.09	-3.96	-5.15	-3.63	6.15	25.59	87.76	-1.63	-58.52
	I+II+III			-.05	.73	-1.12	-3.23	-1.55	4.23	80.10	89.35	-1.01	-45.35
3	W	1.11	6.67										
	I	2.73	16.36	-9.70	8.05	-16.71	-1.45	-1.09	2.45	1.00	44.80	-1.02	-45.59
	II	4.04	24.24	-7.00	25.55	-8.79	-.40	-.34	1.40	1.00	44.97	-.36	-19.93
	III	4.55	27.27	-3.03	34.34	1.52	-.12	.04	1.13	1.27	51.69	.36	3.10
	I+II			-8.79	4.42	-12.75	-2.64	-2.00	3.64	4.39	77.10	-1.05	-46.44
	I+II+III			-6.07	2.95	-7.99	-3.09	-2.71	4.09	10.01	84.30	-.00	-41.32
4	W	.17	2.36										
	I	.30	4.61	-2.55	10.91	-19.25	-1.24	-1.76	2.24	2.99	71.43	-4.10	-76.55
	II	.72	8.61	-4.30	30.16	-12.79	-.87	-.42	1.87	2.35	66.94	-1.49	-56.06
	III	1.41	16.97	-8.36	42.95	-6.85	-.97	-.16	1.97	1.54	57.02	-.40	-21.90
	I+II			-3.27	5.45	-16.02	-3.10	-2.94	4.16	11.62	85.08	-3.72	-74.97
	I+II+III			-4.97	3.64	-12.96	-7.24	-3.56	9.24	15.21	86.24	-2.29	-66.43
5	W	<.01	<.24										
	I	<.01	<.24	.30	11.15	-19.25	.00	-1.73	1.00	56.72	85.99	-79.42	-89.28
	II	.06	1.45	-1.21	30.40	-14.02	-5.00	-.46	6.00	13.06	85.62	-9.63	-84.07
	III	.12	2.91	-1.45	44.40	-8.39	[illegible]	-.19	2.00	8.49	83.28	-2.85	-70.69
	I+II			[illegible]	5.58	-16.62	-5.00	-2.98	6.00	67.95	89.16	-22.86	-87.50
	I+II+III			[illegible]	3.72	-13.85	-11.00	-3.72	12.00	87.82	89.35	-14.28	-86.00
6	W	<.01	<.48										
	I	<.01	<.43										
	II	<.01	<.46										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.77										
	I	<.01	<.97										
	II	<.01	<.97										
	III	<.01	<.97										
	I+II												
	I+II+III												

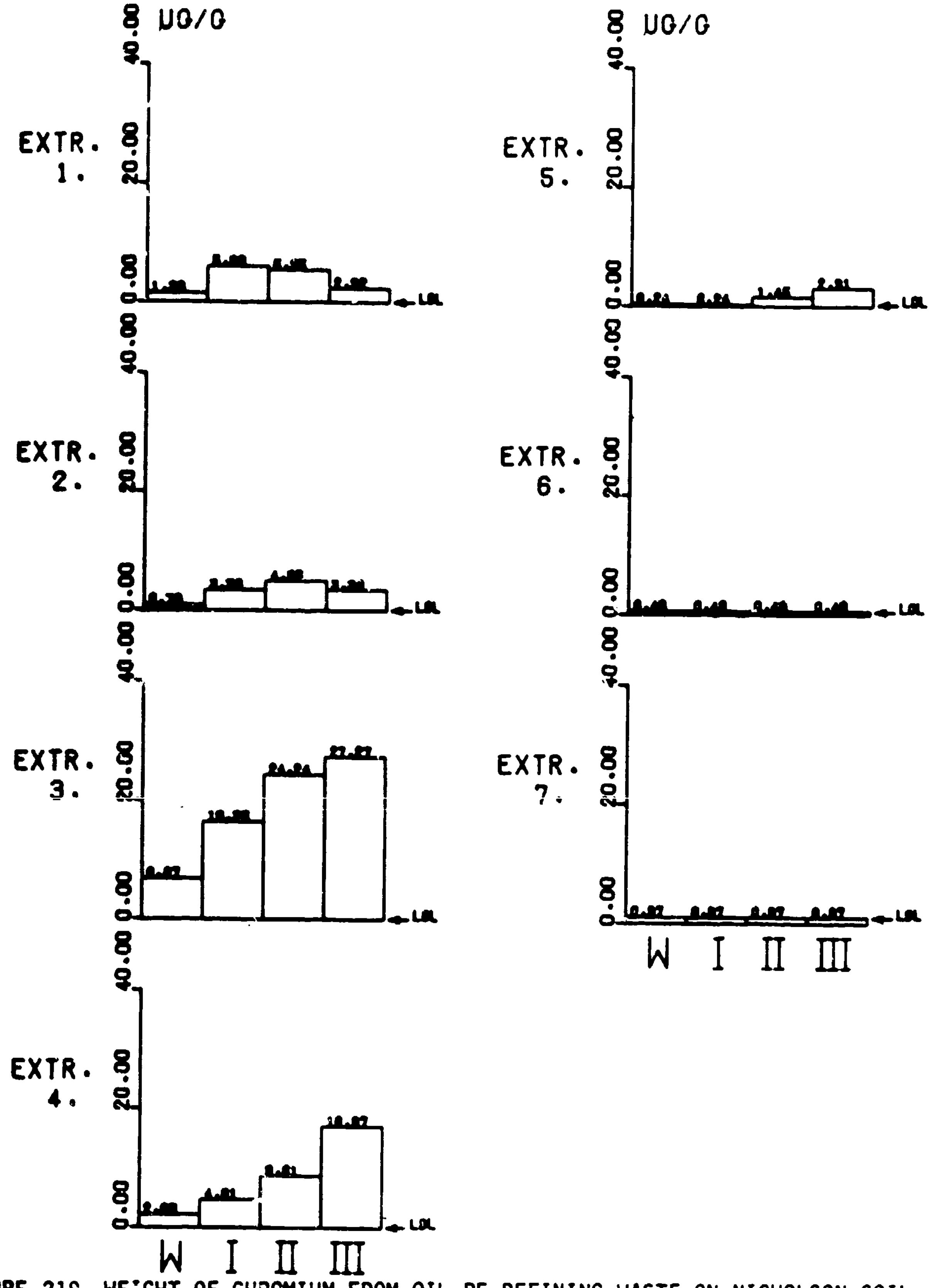


FIGURE 21S. WEIGHT OF CHROMIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

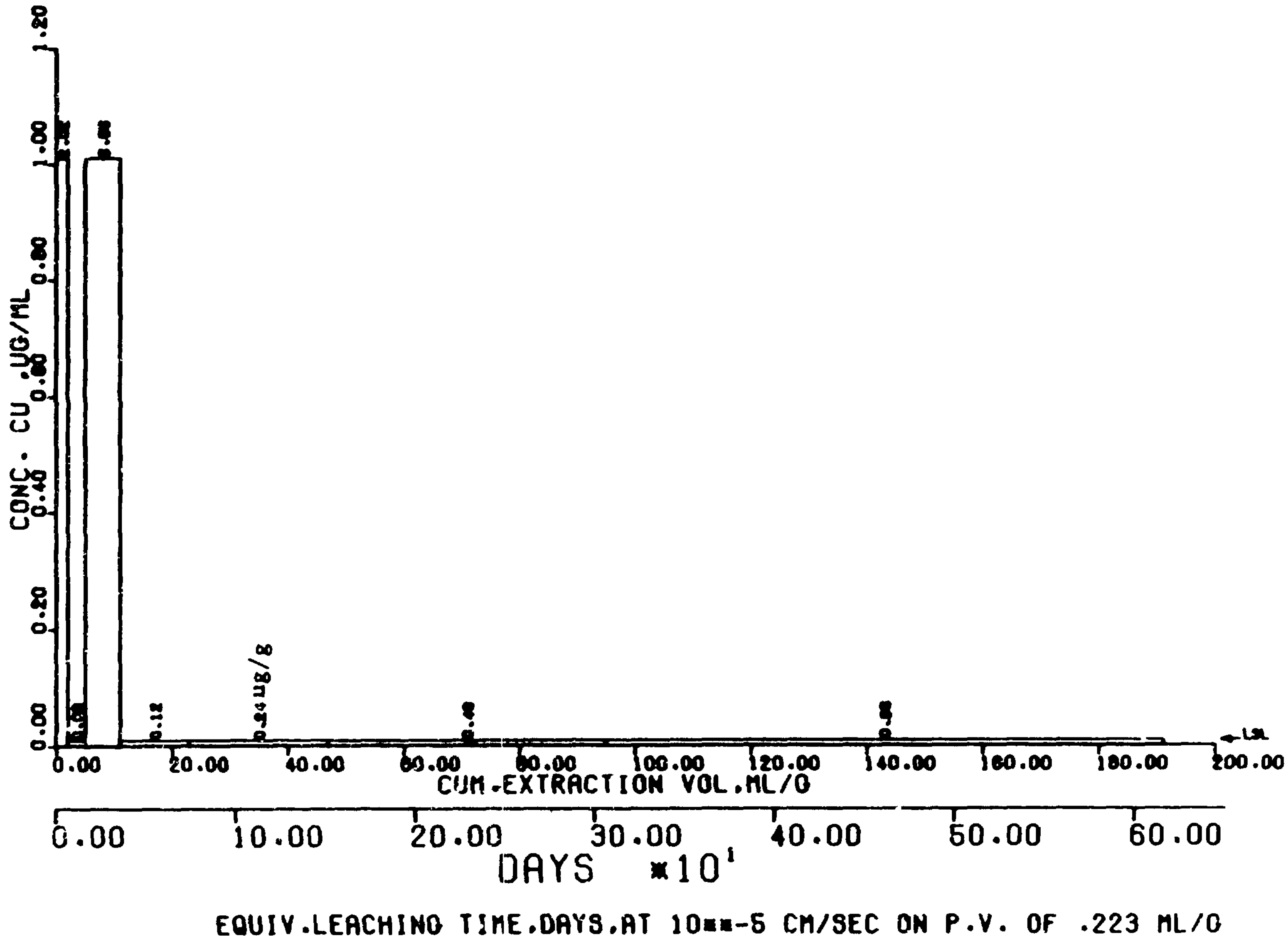


FIGURE 219. EXTRACTION OF COPPER FROM OIL RE-REFINING WASTE (B).

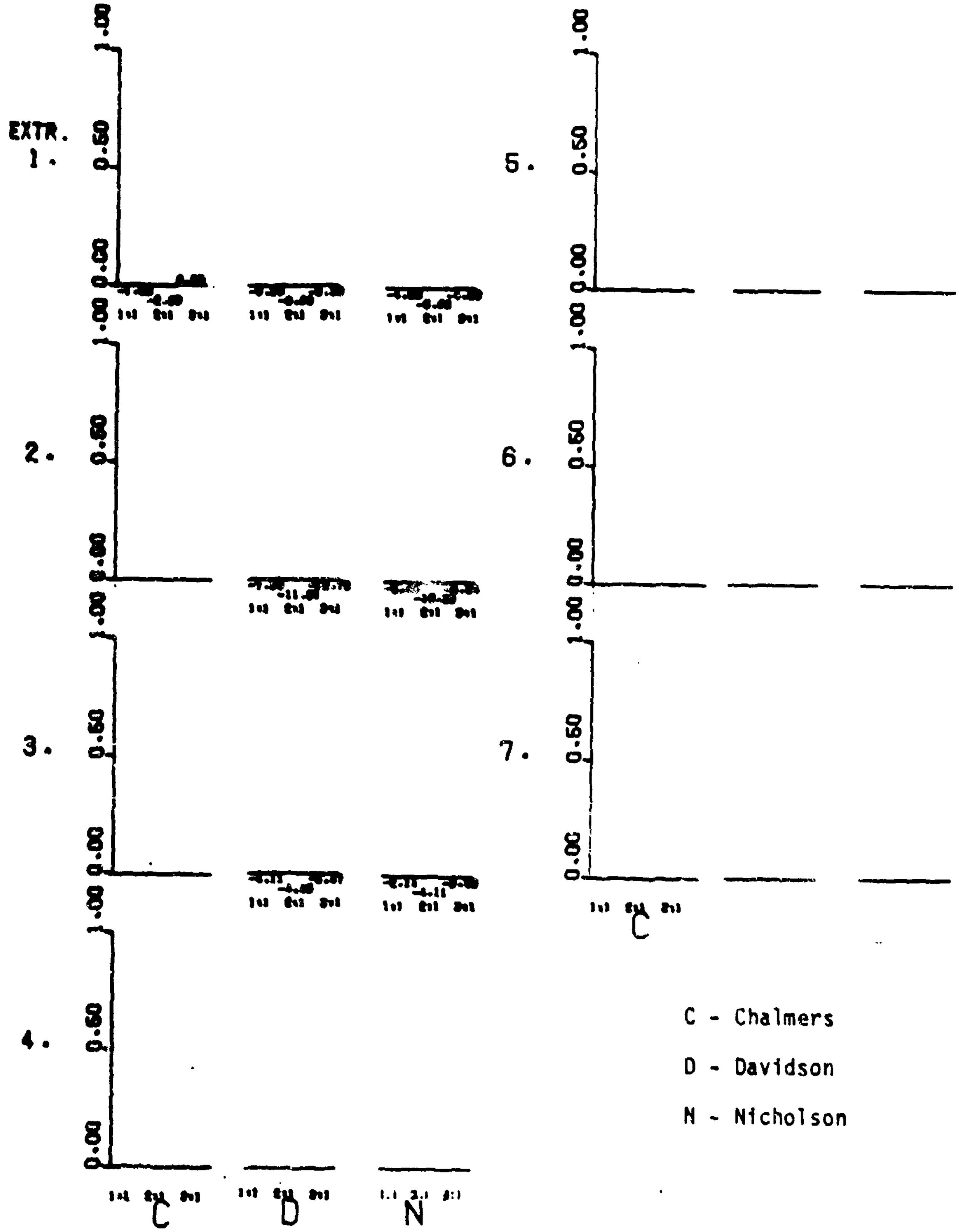


FIGURE 220. COMPARING FRACTION COPPER RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 116. COPPER FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	1.01	2.02										
	I	2.02	4.04	-2.02	2.02	-2.02	-1.00	-1.00	2.00	4.77	78.17	-.50	-26.57
	II	3.03	6.06	-2.02	4.04	-2.02	-.50	-.50	1.50	3.18	72.55	-.33	-18.43
	III	1.01	2.02	4.04	6.06	4.04	.67	.67	.33	12.54	85.44	2.00	63.43
	I+II			-2.02	1.01	-2.02	-2.00	-2.00	3.00	13.39	85.73	-.67	-33.69
	I+II+III			.00	.67	.00	.00	.00	1.00	94.90	89.40	.00	.00
2	W	.01	.03										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	1.01	6.06										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	.01	.12										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	.01	.24										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	.01	.48										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	.01	.96										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

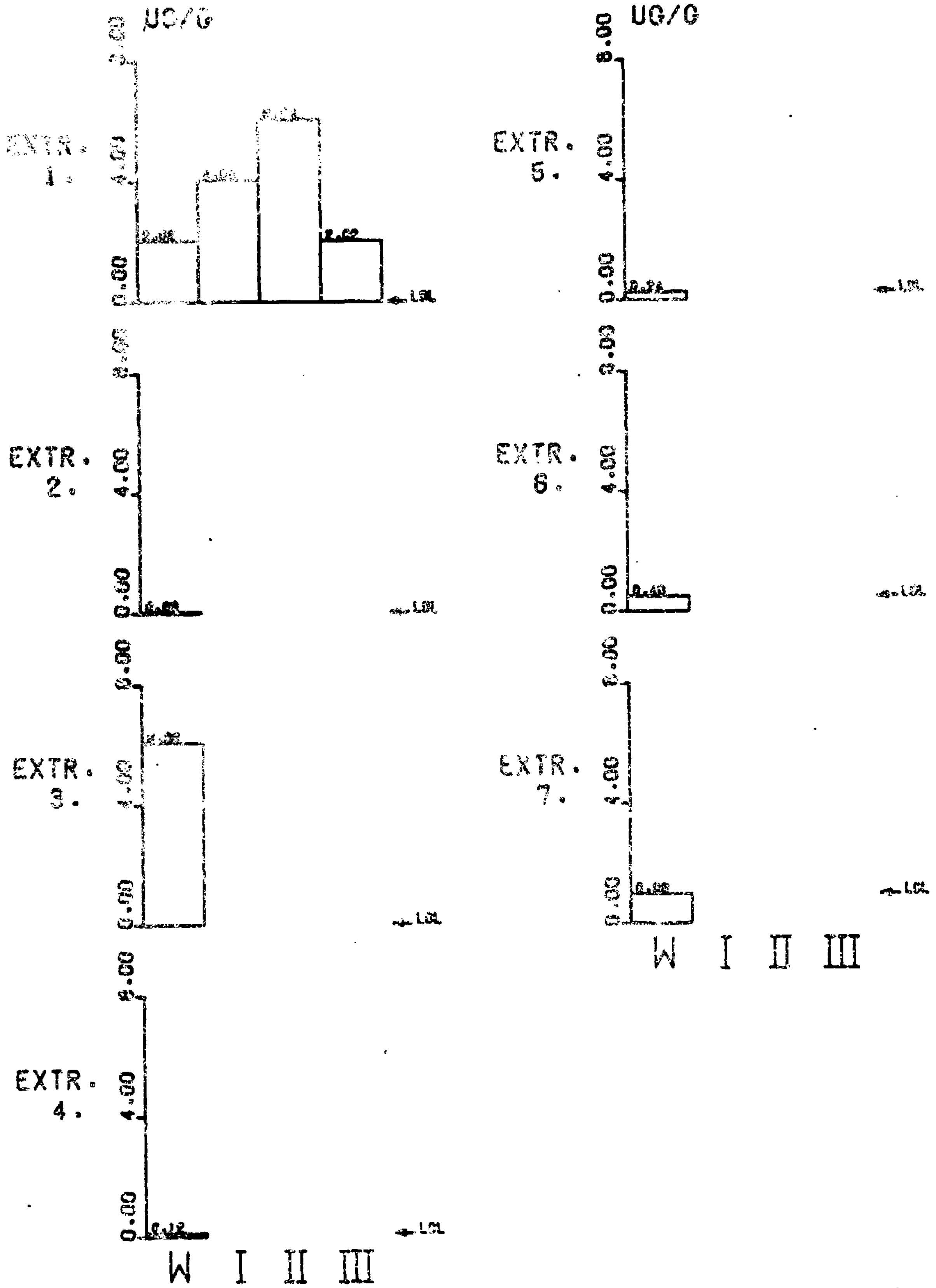


FIGURE 221. WEIGHT OF COPPER FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 117. COPPER FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	1.01	2.02										
	I	7.07	14.14	-12.12	2.02	-12.12	-6.00	-6.00	7.00	4.43	77.29	-.86	-40.60
	II	10.10	20.20	-6.06	14.14	-6.06	-.43	-.43	1.43	3.40	73.62	-.30	-16.70
	III	9.09	18.18	2.02	20.20	2.02	.10	.10	.90	4.23	76.69	.11	6.34
	I+II			-9.09	1.01	-9.09	-9.00	-9.00	10.00	13.91	85.89	-.90	-41.99
	I+II+III			-5.39	.67	-5.39	-8.00	-8.00	9.00	36.14	88.42	-.89	-41.63
2	W	.01	.03										
	I	1.01	3.03	-3.00	2.05	-15.12	-100.00	-7.30	101.	19.70	87.09	-4.99	-78.67
	II	2.02	6.06	-3.03	17.17	-9.09	-1.00	-.53	2.00	10.84	84.73	-1.50	-56.31
	III	4.04	12.12	-6.06	26.26	-4.04	-1.00	-.15	2.00	5.84	80.28	-.33	-18.43
	I+II			-3.02	1.03	-12.11	-201.00	-11.81	202.	45.30	88.74	-4.00	-75.95
	I+II+III			-4.03	.60	-9.42	-403.00	-13.70	404.	53.21	88.92	-2.33	-66.70
3	W	1.01	6.06										
	I	4.04	24.24	-10.10	8.11	-33.30	-3.00	-4.11	4.00	1.71	59.71	-1.37	-53.95
	II	3.03	18.18	6.06	41.41	-3.03	.25	-.07	.75	3.95	75.79	-.17	-9.46
	III	5.05	30.30	-12.12	44.44	-16.16	-.67	-.36	1.67	1.94	62.67	-.53	-28.07
	I+II			-6.06	4.06	-18.17	-2.00	-4.48	3.00	14.46	86.04	-2.00	-63.42
	I+II+III			-8.08	2.70	-17.50	-4.00	-6.47	5.00	20.49	87.21	-1.73	-60.00
4	W	<.01	<.12										
	I	<.01	<.12										
	II	<.01	<.12										
	III	1.01	12.12										
	I+II												
	I+II+III												
5	W	<.01	<.24										
	I	<.01	<.24										
	II	<.01	<.24										
	III	<.01	<.24										
	I+II												
	I+II+III												
6	W	<.01	<.48										
	I	<.01	<.48										
	II	<.01	<.48										
	III	<.01	<.48										
	I+II												
	I+II+III												
7	W	<.01	<.96										
	I	<.01	<.96										
	II	<.01	<.96										
	III	<.01	<.96										
	I+II												
	I+II+III												

The remainder of the table was not calculated because of the prevalence of values below the detection limit.

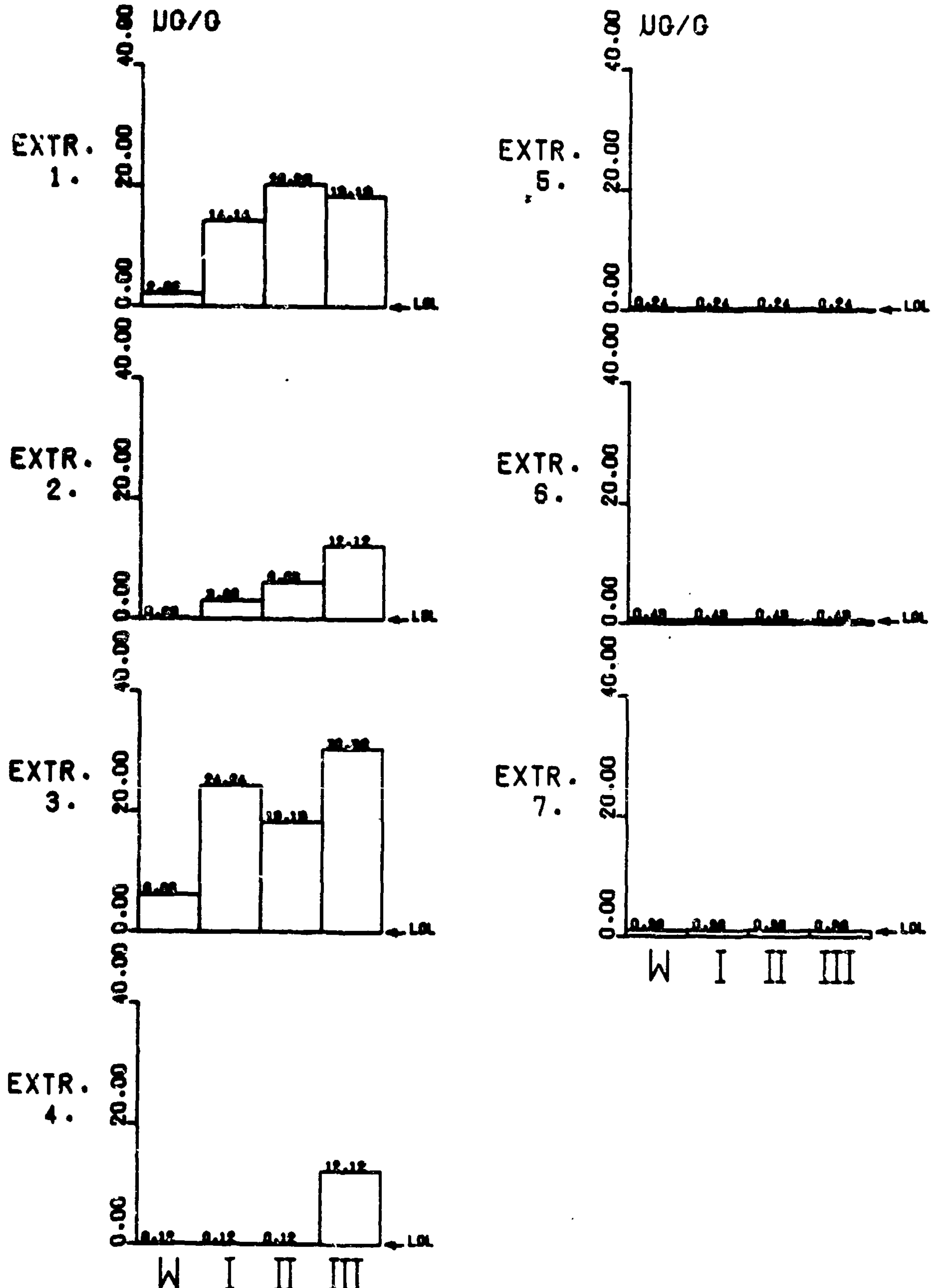


FIGURE 222. WEIGHT OF COPPER FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 118. COPPER FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	1.01	2.02										
	I	5.05	10.10	-8.08	2.02	-8.08	-4.00	-4.00	5.00	1.65	58.71	-.80	-38.66
	II	7.07	14.14	-4.04	10.10	-4.04	-.40	-.40	1.40	1.46	55.61	-.29	-15.95
	III	5.05	10.10	4.04	14.14	4.04	.29	.29	.71	2.85	70.64	.40	21.80
	I+II			-6.06	1.01	-6.06	-6.00	-6.00	7.00	6.13	80.74	-.86	-40.60
	I+II+III			-2.69	.67	-2.69	-4.00	-4.00	5.00	21.21	87.30	-.80	-38.66
2	W	.01	.03										
	I	1.01	3.03	-3.00	2.05	-11.08	-100.00	-5.40	101.	4.50	77.46	-3.66	-74.71
	II	3.03	9.09	-6.06	13.13	-10.10	-2.00	-.77	3.00	1.61	58.09	-1.11	-48.01
	III	4.04	12.12	-3.03	23.23	1.01	-.33	.04	1.33	2.12	64.76	.08	4.76
	I+II			-4.53	1.03	-10.59	-302.00	-10.33	303.	8.54	83.32	-2.33	-66.77
	I+II+III			-4.03	.68	-6.72	-403.00	-9.84	404.	16.60	86.57	-1.66	-59.00
3	W	1.01	6.06										
	I	2.02	12.12	-6.06	8.11	-17.14	-1.00	-2.11	2.00	.62	31.95	-1.41	-54.74
	II	3.03	18.18	-6.06	25.25	-16.16	-.50	-.64	1.50	.47	25.16	-.89	-41.63
	III	3.03	18.18	.00	41.41	1.01	.00	.02	1.00	1.41	54.74	.06	3.18
	I+II			-6.06	4.06	-16.65	-2.00	-4.11	3.00	3.60	74.49	-1.83	-61.37
	I+II+III			-4.04	2.70	-19.76	-2.00	-3.98	3.00	10.45	84.53	-1.78	-60.62
4	W	<.01	< .12										
	I	<.01	< .12										
	II	<.01	< .12										
	III	1.01	12.12										
	I+II												
	I+II+III												
5	W	<.01	< .24										
	I	<.01	< .24										
	II	<.01	< .24										
	III	<.01	< .24										
	I+II												
	I+II+III												
6	W	<.01	< .48										
	I	<.01	< .48										
	II	<.01	< .48										
	III	<.01	< .48										
	I+II												
	I+II+III												
7	W	<.01	< .96										
	I	<.01	< .96										
	II	<.01	< .96										
	III	<.01	< .96										
	I+II												
	I+II+III												

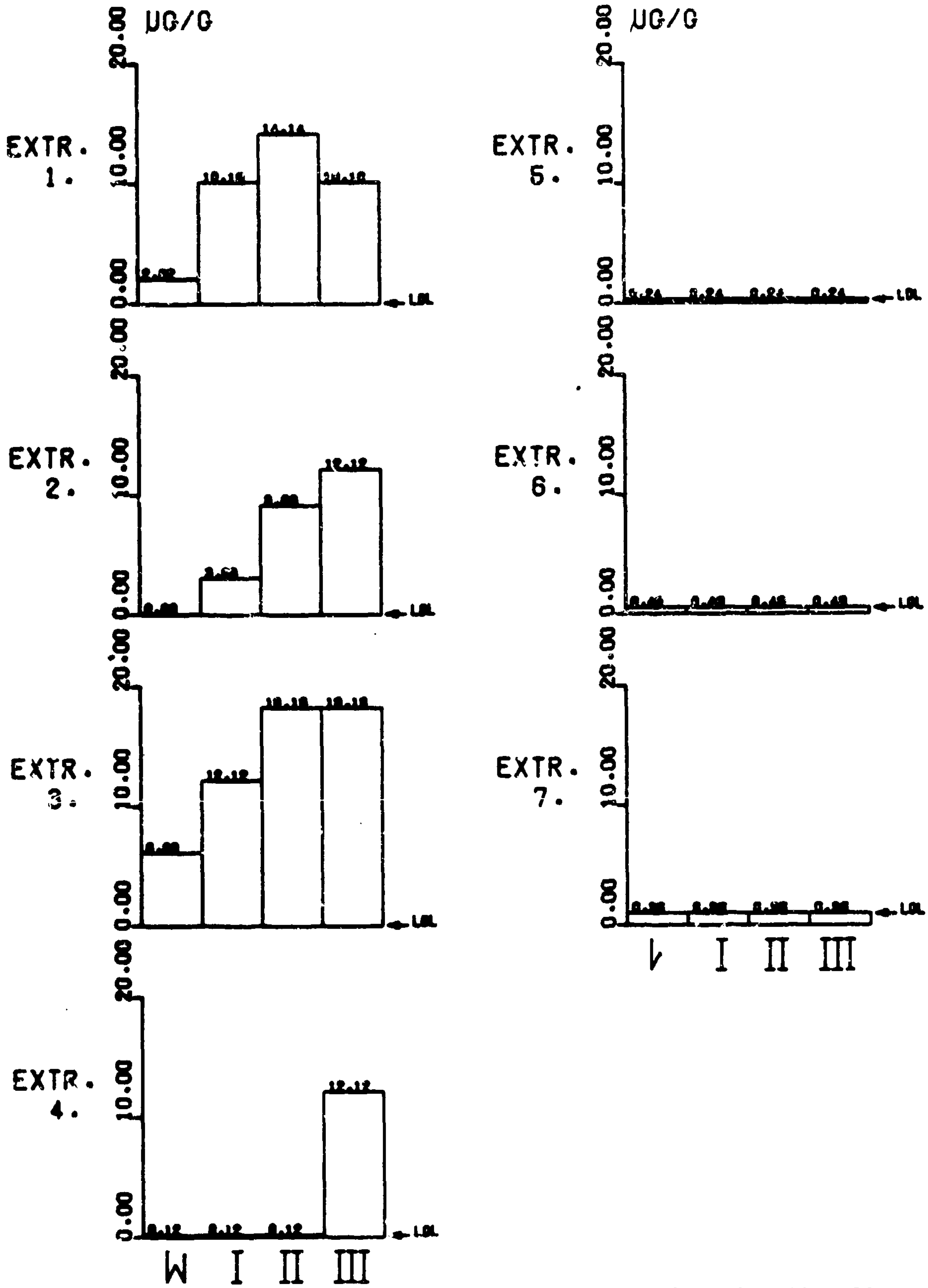


FIGURE 223. WEIGHT OF COPPER FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

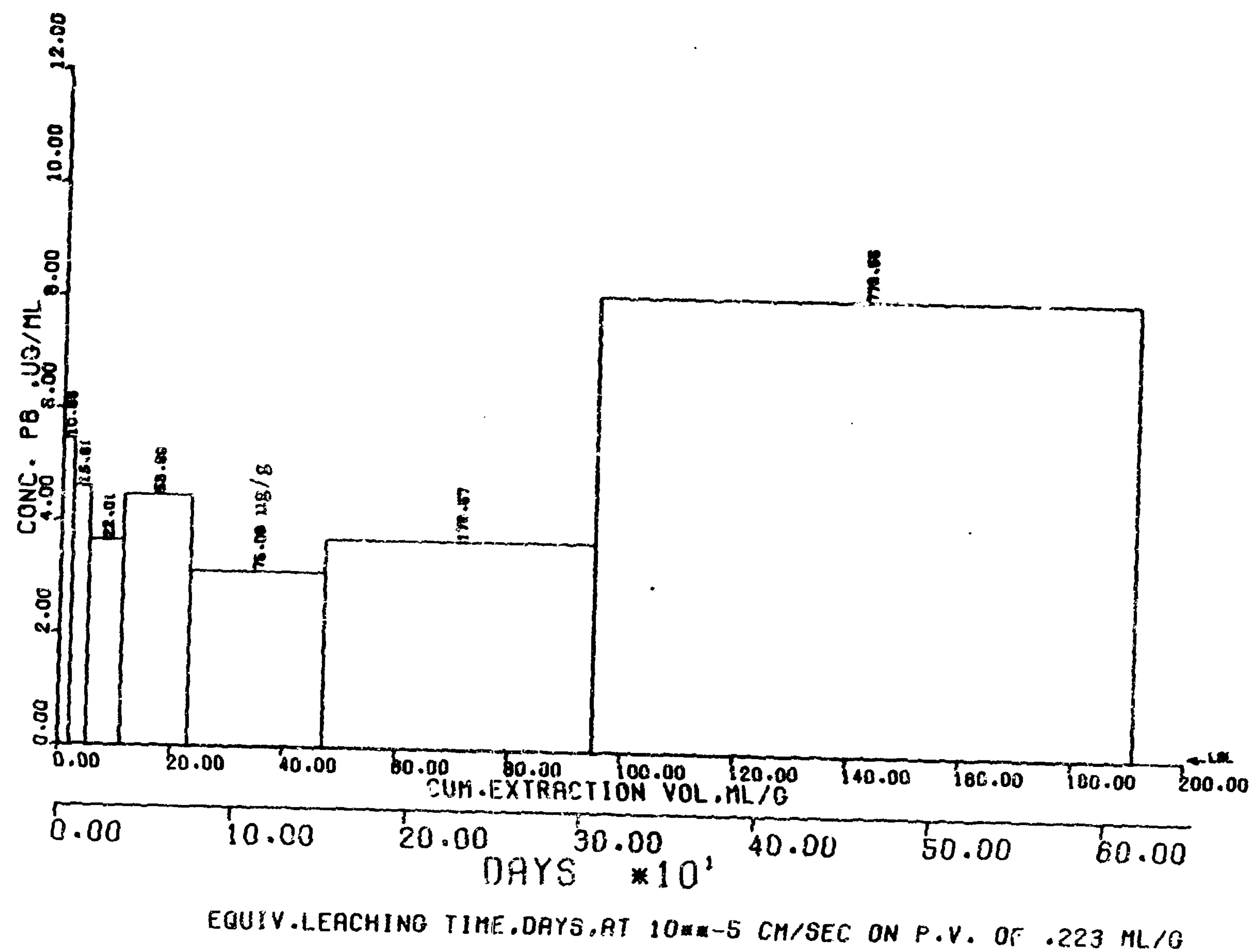


FIGURE 224. EXTRACTION OF LEAD FROM OIL RE-REFINING WASTE (B).

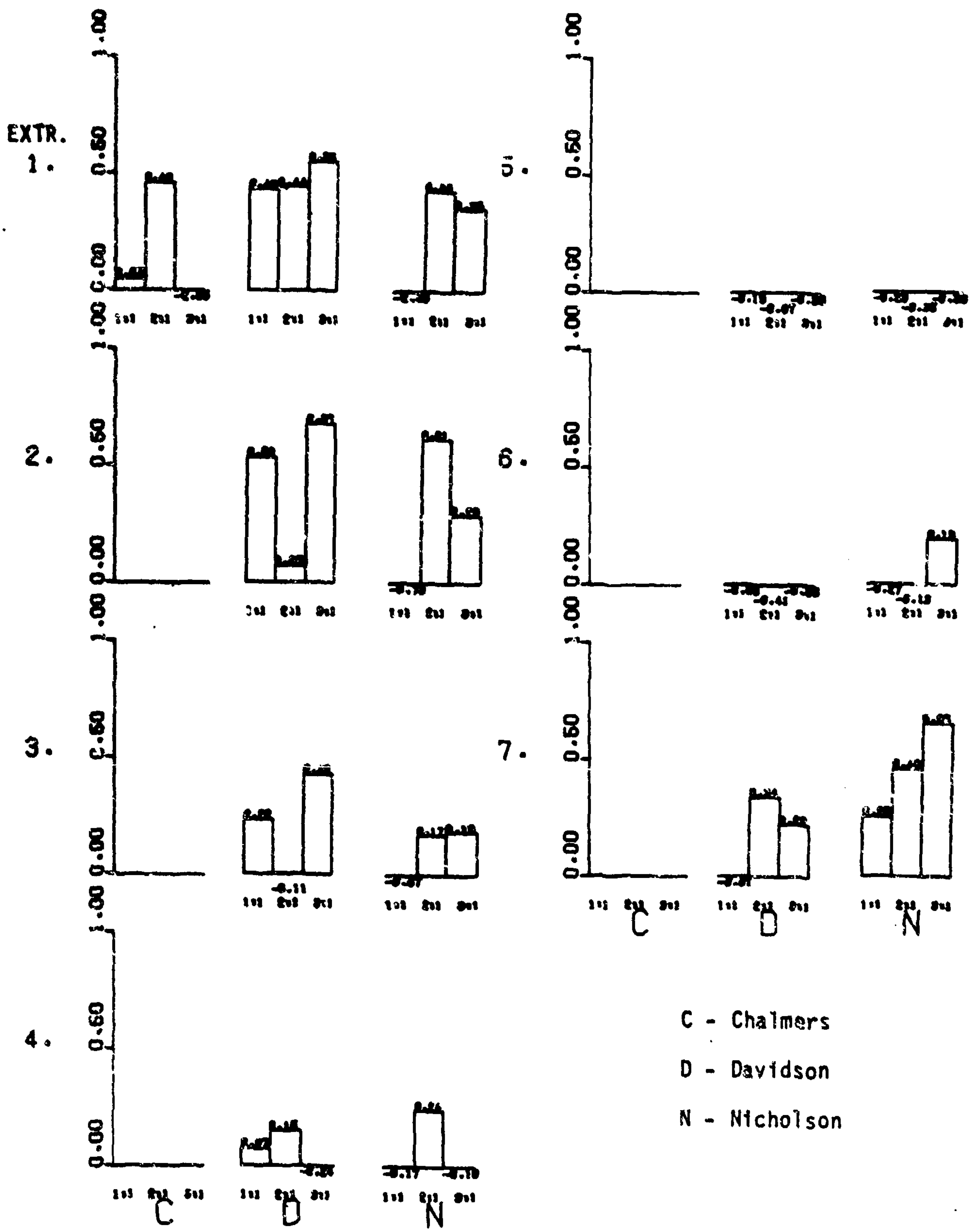


FIGURE 225. COMPARING FRACTION LEAD RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 119. LEAD FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NO.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	5.44	10.88										
	I	5.18	10.37	.52	10.88	.52	.05	.05	.95	9.55	84.02	.05	2.85
	II	2.95	5.90	4.47	10.37	4.47	.43	.43	.57	17.45	86.72	.76	37.11
	III	16.60	33.21	-27.30	5.90	-27.30	-4.63	-4.63	5.63	2.14	65.03	-.82	-39.43
	I+II			2.49	5.44	2.49	.46	.46	.54	67.60	89.15	.84	40.07
	I+II+III			-7.44	3.63	-7.44	-2.05	-2.05	3.05	26.12	87.80	-.67	-33.91
2	W	4.60	13.31										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	3.67	22.01										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	4.47	53.69										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	3.13	75.08										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	3.72	178.57										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	8.09	776.55										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

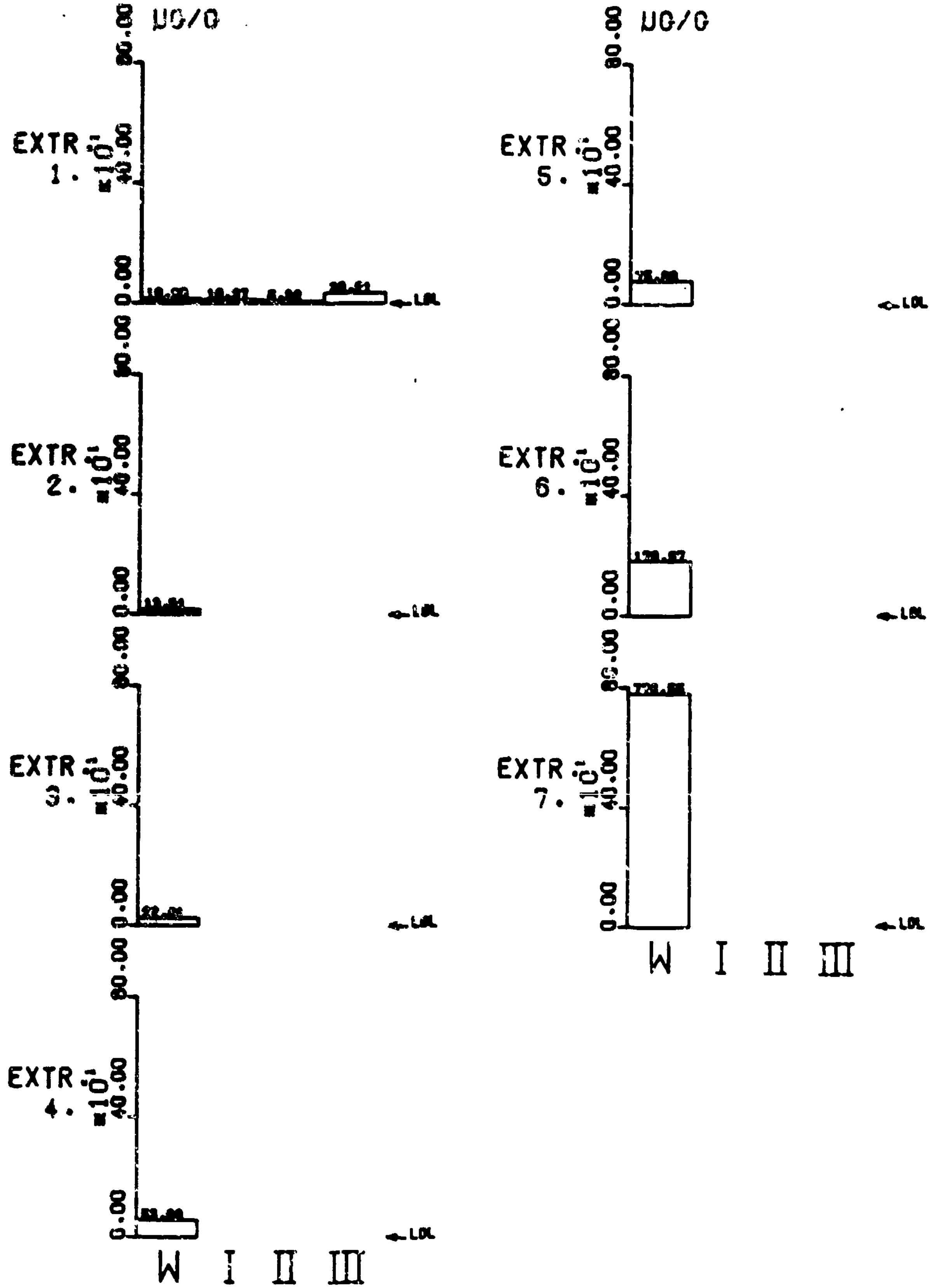


FIGURE 226. WEIGHT OF LEAD FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 120. LEAD FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	5.44	10.00										
	I	3.10	6.20	4.60	10.00	4.60	.43	.43	.57	25.59	87.76	.76	37.05
	II	3.05	6.10	.10	6.20	.10	.02	.02	.98	25.27	87.73	.02	.97
	III	2.46	4.92	1.18	6.10	1.18	.19	.19	.81	31.55	88.18	.24	13.49
	I+II			2.39	5.44	2.39	.44	.44	.56	101.00	89.44	.78	38.12
	I+II+III			1.99	3.63	1.99	.55	.55	.45	283.03	89.80	1.21	50.50
2	W	4.60	13.81										
	I	1.79	5.38	8.43	24.70	13.11	.61	.53	.39	31.05	88.16	2.44	67.69
	II	5.64	16.93	-11.55	11.58	-11.45	-2.15	-.99	3.15	8.42	83.23	-.68	-34.06
	III	1.03	3.09	13.85	23.03	15.03	.82	.65	.18	54.74	88.95	4.87	78.39
	I+II			-1.56	12.35	.83	-.23	.07	1.23	36.47	88.43	.10	5.61
	I+II+III			3.57	8.23	5.56	.78	.68	.22	454.24	89.87	5.40	79.52
3	W	3.67	22.01										
	I	4.07	24.40	-2.39	46.70	10.72	-.11	.23	1.11	6.75	81.58	.44	23.73
	II	4.78	28.65	-4.26	35.98	-15.71	-.17	-.44	1.17	4.83	78.29	-.55	-28.73
	III	3.13	18.80	9.86	51.69	24.08	.34	.48	.66	9.52	84.00	1.32	52.93
	I+II			-3.32	23.35	-2.49	-.30	-.11	1.30	21.32	87.32	-.17	-9.86
	I+II+III			1.07	15.57	6.63	.15	.43	.85	74.79	89.23	1.06	46.63
4	W	4.47	53.69										
	I	4.77	57.26	-3.57	100.40	7.15	-.07	.07	1.07	2.81	70.44	.12	7.12
	II	2.83	33.92	23.34	93.24	7.64	.41	.08	.59	4.77	78.15	.23	12.69
	III	8.17	98.01	-64.09	85.61	-39.21	-1.89	-.46	2.89	1.17	49.51	-.40	-21.80
	I+II			9.89	50.20	7.40	.37	.15	.63	10.60	84.92	.44	23.56
	I+II+III			-14.77	33.47	-8.14	-.83	-.24	1.83	13.89	85.88	-.25	-13.99
5	W	3.13	75.00										
	I	4.83	115.89	-40.01	175.47	-33.66	-.54	-.19	1.54	1.04	46.08	-.29	-16.19
	II	4.23	101.55	14.34	209.13	21.98	.12	.11	.88	1.73	60.01	.22	12.21
	III	6.94	166.62	-65.08	187.15	-104.29	-.64	-.56	1.64	.30	16.61	-.63	-32.04
	I+II			-13.23	87.74	-5.84	-.35	-.07	1.35	5.95	80.46	-.12	-6.56
	I+II+III			-30.52	58.49	-38.65	-1.22	-.66	2.22	7.62	82.53	-.70	-34.84
6	W	3.72	178.57										
	I	7.28	349.21	-170.65	354.04	-204.30	-.96	-.58	1.96	-.14	-8.20	-.59	-30.33
	II	6.46	310.28	38.93	558.34	60.91	.11	.11	.89	.69	34.71	.20	11.11
	III	5.45	261.41	48.87	497.43	-55.42	.16	-.11	.84	.38	20.66	-.21	-11.97
	I+II			-65.86	177.02	-71.69	-.74	-.41	1.74	1.52	56.71	-.46	-24.80
	I+II+III			-27.61	118.01	-66.27	-.46	-.56	1.46	4.54	77.58	-.76	-37.25
7	W	8.09	776.55										
	I	6.06	582.22	194.33	1138.60	-9.97	.25	-.01	.75	.25	13.89	-.02	-.98
	II	2.62	251.49	330.73	1140.57	391.64	.57	.34	.43	2.17	65.25	1.56	57.2
	III	3.43	329.24	-77.75	748.93	-133.17	-.31	-.18	1.31	.06	3.62	-.40	-22.02
	I+II			262.53	565.30	198.83	.68	.34	.32	3.97	75.85	1.52	56.62
	I+II+III			149.10	376.87	82.83	.58	.22	.42	4.96	78.61	.75	37.04

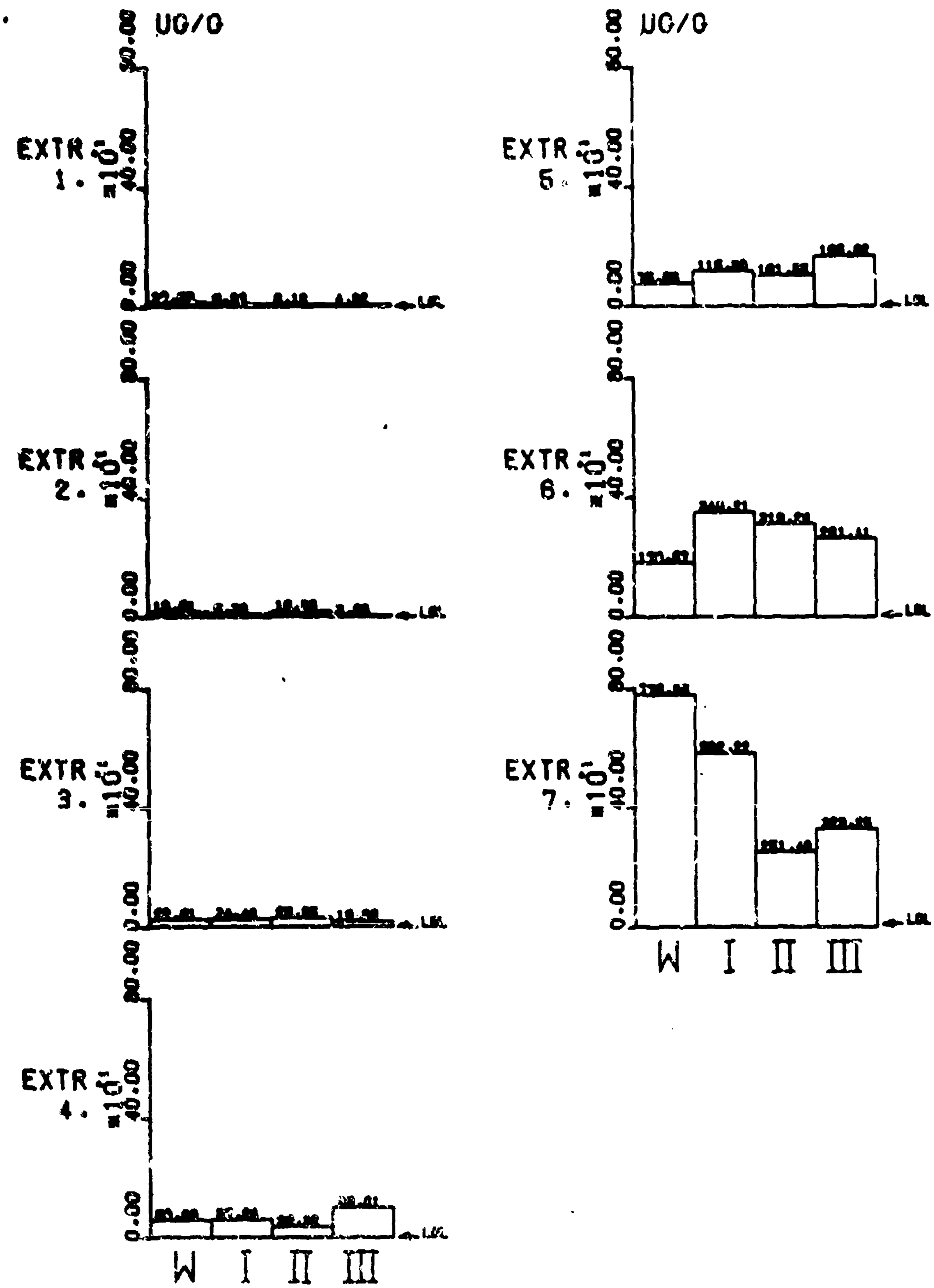


FIGURE 227. WEIGHT OF LEAD FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL(B).

TABLE 121. LEAD FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	5.44	11.00										
	I	10.05	37.71	-26.82	10.80	-26.82	-2.46	-2.46	3.46	1.93	62.61	-.71	-35.43
	II	3.12	6.25	31.46	37.71	31.46	.83	.83	.17	20.90	87.27	5.04	78.77
	III	3.55	7.10	-.05	6.25	-.05	-.14	-.14	1.14	13.92	85.89	.12	-6.83
	I+II			2.32	5.44	2.32	.43	.43	.57	44.53	89.11	.74	36.60
	I+II+III			1.26	3.63	1.26	.35	.35	.65	126.06	89.55	.53	28.09
2	W	4.60	13.81										
	I	1.65	4.95	8.86	24.70	-17.96	.64	-.73	.36	16.49	86.53	-3.63	-74.59
	II	1.10	3.30	1.65	42.66	33.11	.33	.78	.67	40.22	88.58	10.04	84.31
	III	3.50	10.49	-7.19	9.55	-8.04	-2.18	-.84	3.18	8.73	83.47	-.77	-37.47
	I+II			5.26	12.35	7.58	.76	.61	.24	125.33	89.54	4.59	77.71
	I+II+III			1.11	8.23	2.37	.24	.29	.76	86.16	89.34	.68	34.15
3	W	3.67	22.01										
	I	5.90	35.40	-13.39	46.70	-31.35	-.61	-.67	1.61	1.93	62.58	-.89	-41.53
	II	4.87	29.21	6.19	70.06	39.31	.17	.50	.83	4.76	78.13	1.35	53.39
	III	3.44	20.66	8.54	30.75	.51	.29	.01	.71	4.84	78.34	.02	1.41
	I+II			-3.60	23.35	3.98	-.33	.17	1.33	13.91	85.89	.27	15.23
	I+II+III			.45	15.57	2.02	.06	.18	.94	43.79	88.69	.41	22.27
4	W	4.47	53.69										
	I	3.28	39.38	14.31	100.40	-17.04	.27	-.17	.73	2.10	64.50	-.43	-23.40
	II	3.13	37.56	1.83	117.44	41.13	.05	.35	.95	3.75	75.06	1.10	47.60
	III	6.01	72.16	-34.60	76.31	-34.09	-.92	-.45	1.92	.91	42.23	-.47	-25.29
	I+II			8.07	50.20	12.04	.30	.24	.70	11.25	84.92	.64	32.67
	I+II+III			-6.15	33.47	-3.33	-.34	-.10	1.34	12.28	85.35	-.14	-7.89
5	W	3.13	75.08										
	I	4.11	98.66	-23.58	175.47	-40.63	-.31	-.23	1.31	.60	30.87	-.41	-22.38
	II	6.71	160.99	-62.33	216.10	-21.20	-.63	-.10	1.63	.49	25.96	-.13	-7.50
	III	5.15	123.66	37.33	237.30	3.24	.23	.01	.77	.83	39.75	.03	1.50
	I+II			-42.96	87.74	-30.91	-1.14	-.35	2.14	2.09	64.44	-.38	-21.01
	I+II+III			-16.20	58.49	-19.53	-.65	-.33	1.65	6.77	81.60	-.47	-25.35
6	W	3.72	170.57										
	I	4.84	232.56	-53.99	354.04	-94.61	-.30	-.27	1.30	.02	1.23	-.41	-22.14
	II	3.43	164.42	68.14	440.66	46.94	.29	.10	.71	.89	41.71	.29	15.93
	III	1.09	52.49	111.93	401.72	115.17	.68	.29	.32	4.09	76.27	2.19	65.50
	I+II			7.00	177.02	-23.84	.08	-.13	.92	2.13	64.88	-.29	-16.17
	I+II+III			42.03	118.01	22.50	.71	.19	.29	18.36	86.88	1.29	52.13
7	W	8.09	776.55										
	I	4.14	397.52	379.04	1130.69	284.42	.49	.25	.51	.97	44.01	.72	35.58
	II	2.22	212.69	184.83	846.17	231.76	.46	.27	.54	1.56	57.31	1.09	47.46
	III	1.10	105.91	106.78	614.41	221.95	.50	.36	.50	3.84	71.77	2.10	64.49
	I+II			201.93	565.30	258.09	.73	.46	.27	4.30	76.91	2.43	67.61
	I+II+III			223.55	376.87	246.05	.86	.65	.14	15.43	86.29	6.97	81.83

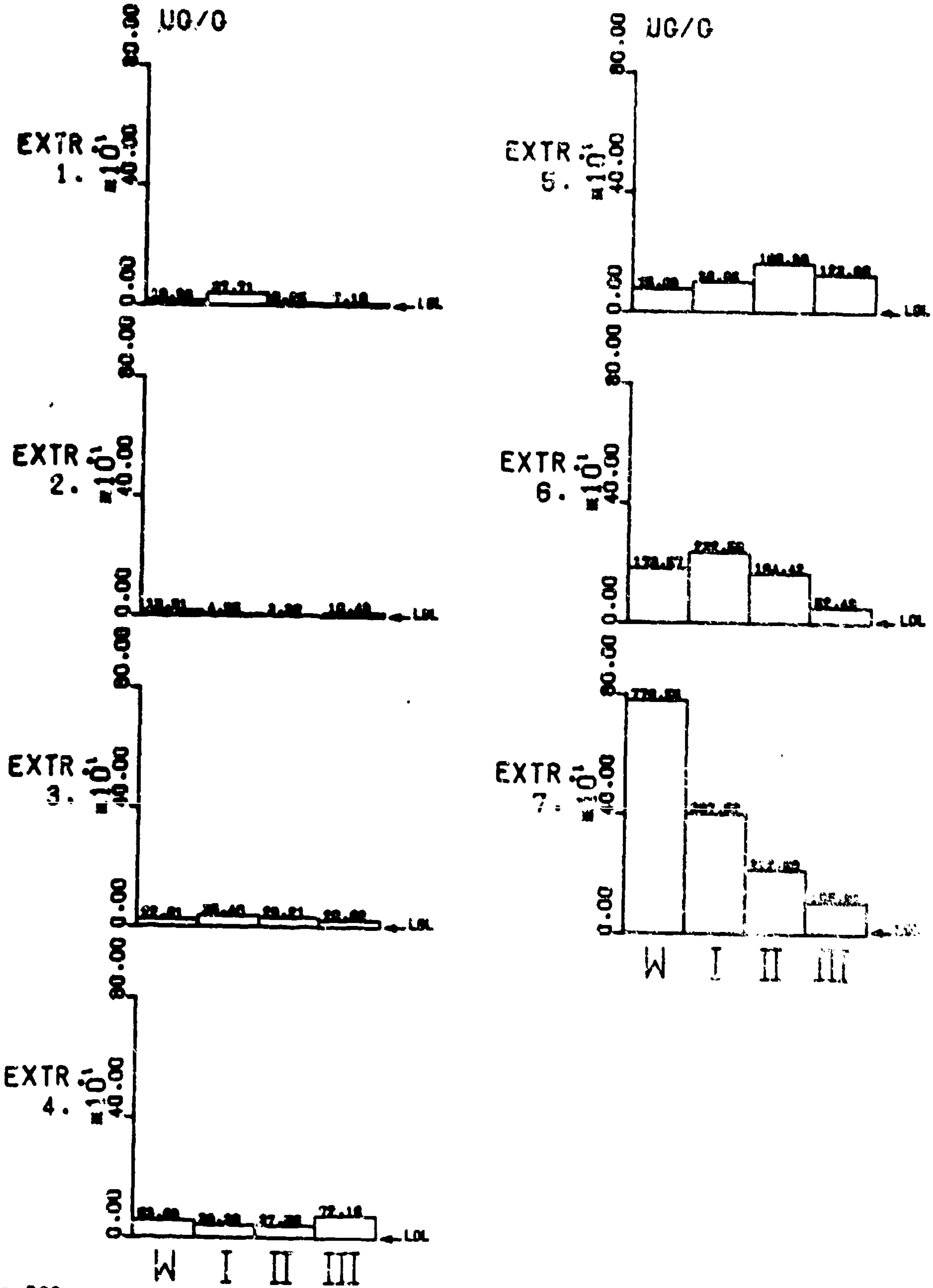


FIGURE 228. WEIGHT OF LEAD FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

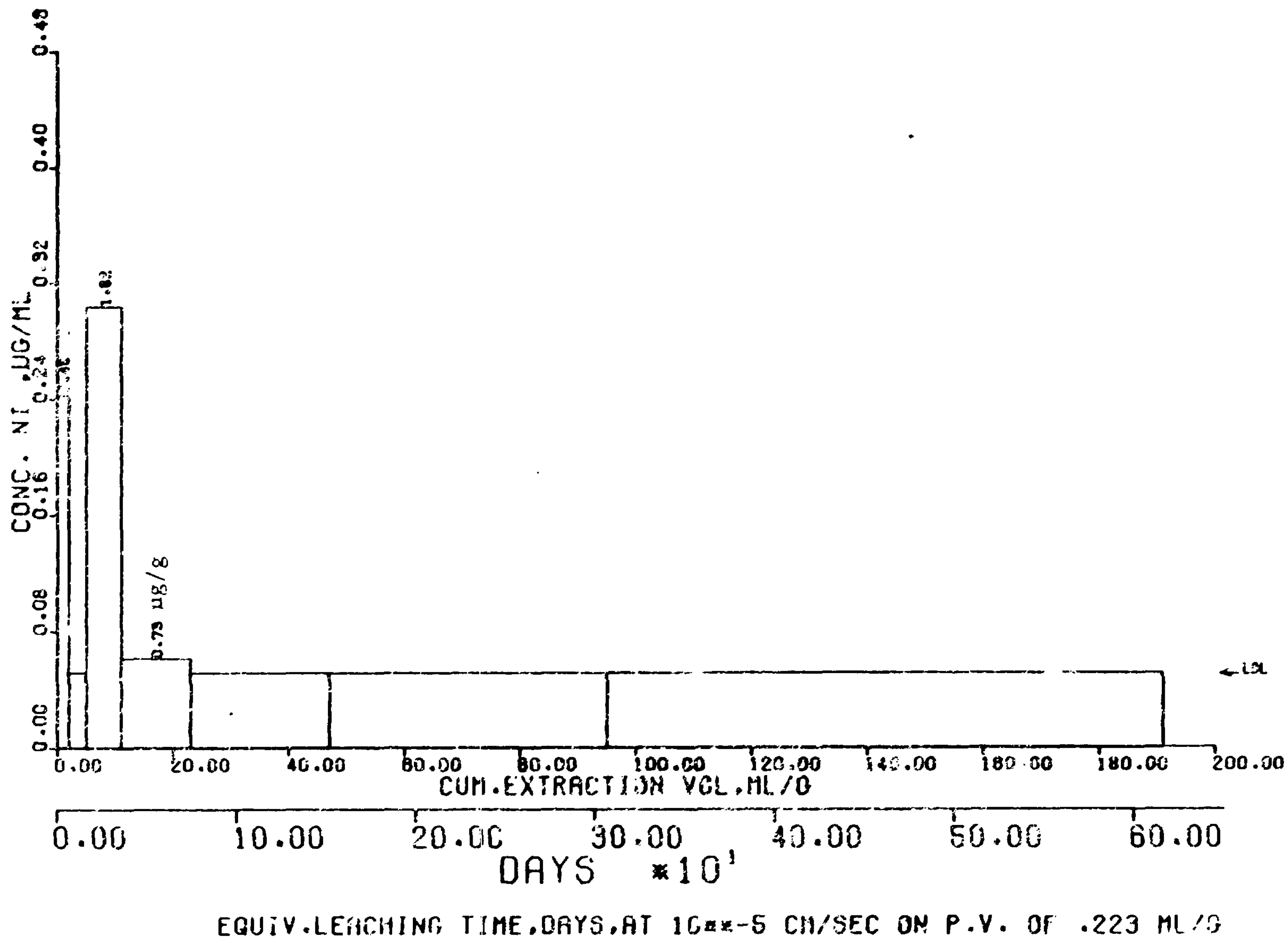


FIGURE 229. EXTRACTION OF NICKEL FROM OIL RE-REFINING WASTE (B).

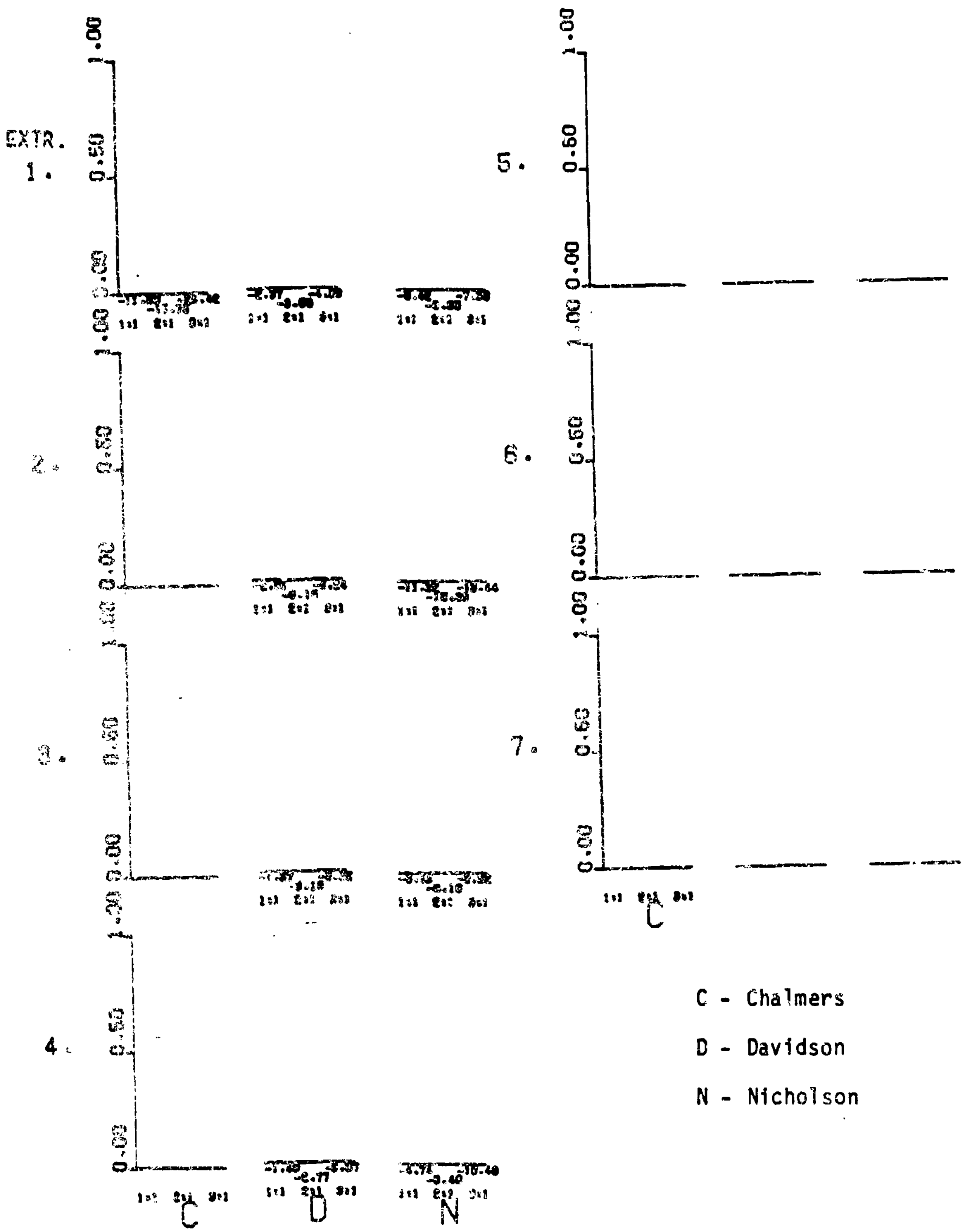


FIGURE 230. COMPARING FRACTION NICKEL RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 122. NICKEL FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.24	.40										
	I	3.83	6.64	-5.50	.40	-5.50	-11.50	-11.50	12.50	3.14	72.33	-.92	-42.61
	II	4.95	9.07	-3.03	6.06	-3.03	-.50	-.50	1.50	2.37	67.15	-.33	-18.43
	III	6.14	12.32	-3.23	9.09	-3.23	-.36	-.36	1.36	1.73	60.03	-.26	-14 70
	I+II			-4.30	.24	-4.30	-17.75	-17.75	18.75	9.88	84.22	-.95	-43.43
	I+II+III			-3.95	.16	-3.95	-24.42	-24.42	25.42	17.01	86.63	-.96	-43.85
2	W	<.05	<.15										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	.30	1.02										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	.06	.73										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	<.05	<1.21										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

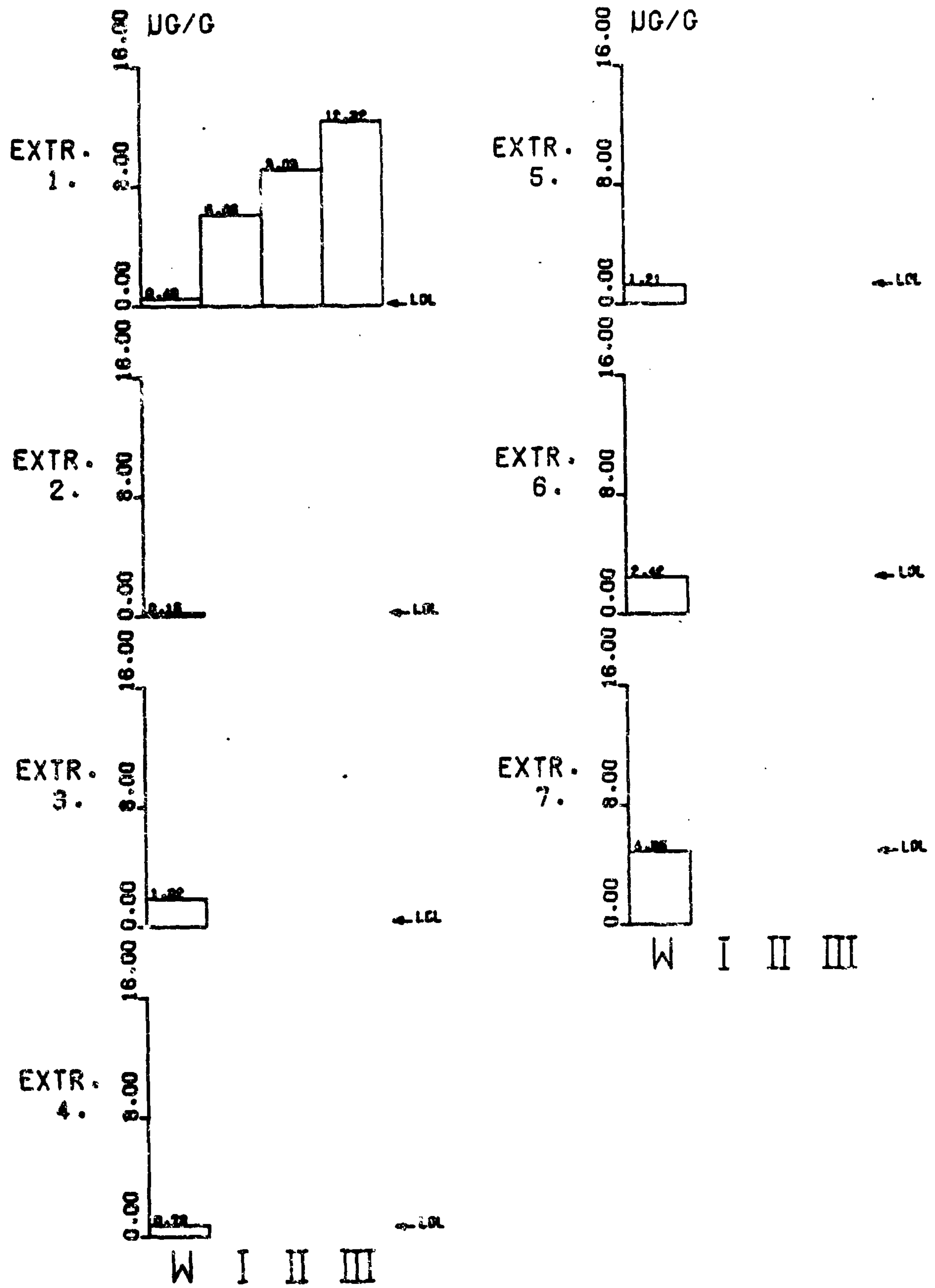


FIGURE 231. WEIGHT OF NICKEL FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 123. NICKEL FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.24	.48										
	I	.82	1.64	-1.15	.48	-1.15	-2.37	-2.37	3.37	8.89	83.58	-.70	-35.13
	II	1.11	2.22	-.59	1.64	-.59	-.36	-.36	1.36	6.80	81.64	-.26	-14.77
	III	1.21	2.42	-.20	2.22	-.20	-.09	-.09	1.09	6.39	81.11	-.08	-4.76
	I+II			-.67	.24	-.87	-3.58	-3.58	4.58	27.48	87.92	-.78	-38.62
	I+II+III			-.65	.16	-.65	-4.00	-4.00	5.00	57.49	89.00	-.80	-39.66
2	W	<.05	<.15										
	I	.26	.79	-.64	.64	-1.79	-4.20	-2.81	5.20	17.66	86.76	-2.27	-66.22
	II	.78	2.33	-1.55	2.42	-2.13	-1.96	-.88	2.96	5.82	80.24	-.91	-42.41
	III	.52	1.55	.79	4.56	.59	.34	.13	.66	10.54	84.58	.38	20.76
	I+II			-1.09	.32	-1.96	-14.40	-6.16	15.40	25.24	87.73	-1.68	-59.23
	I+II+III			-.46	.21	-1.11	-9.20	-5.24	10.20	89.26	89.36	-2.16	-65.13
3	W	.30	1.82										
	I	.57	3.39	-1.58	2.45	-3.36	-.87	-1.37	1.87	3.64	74.62	-.99	-44.74
	II	.92	5.51	-2.12	5.82	-4.25	-.63	-.73	1.63	2.08	64.28	-.77	-37.63
	III	1.11	6.67	-1.15	10.07	-.57	-.21	-.06	1.21	2.27	66.23	-.08	-4.85
	I+II			-1.85	1.23	-3.81	-2.03	-3.10	3.03	10.01	84.29	-1.38	-54.09
	I+II+III			-1.62	.82	-2.73	-2.67	-3.33	3.67	19.97	87.13	-1.23	-50.83
4	W	.06	.73										
	I	.15	1.82	-1.09	3.18	-4.45	-1.50	-1.40	2.50	6.19	80.82	-2.45	-67.80
	II	.16	1.94	-.12	7.64	-4.37	-.07	-.57	1.07	5.84	80.28	-2.26	-66.09
	III	.40	4.85	-2.91	12.01	-3.47	-1.50	-.29	2.50	2.52	68.37	-.72	-35.63
	I+II			-.61	1.59	-4.41	-1.67	-2.77	2.67	27.83	87.94	-4.55	-77.61
	I+II+III			-1.37	1.06	-4.10	-5.67	-3.87	6.67	26.61	87.85	-2.54	-68.49
5	W	<.05	<1.21										
	I	<.05	<1.21										
	II	<.05	<1.21										
	III	.07	1.70										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

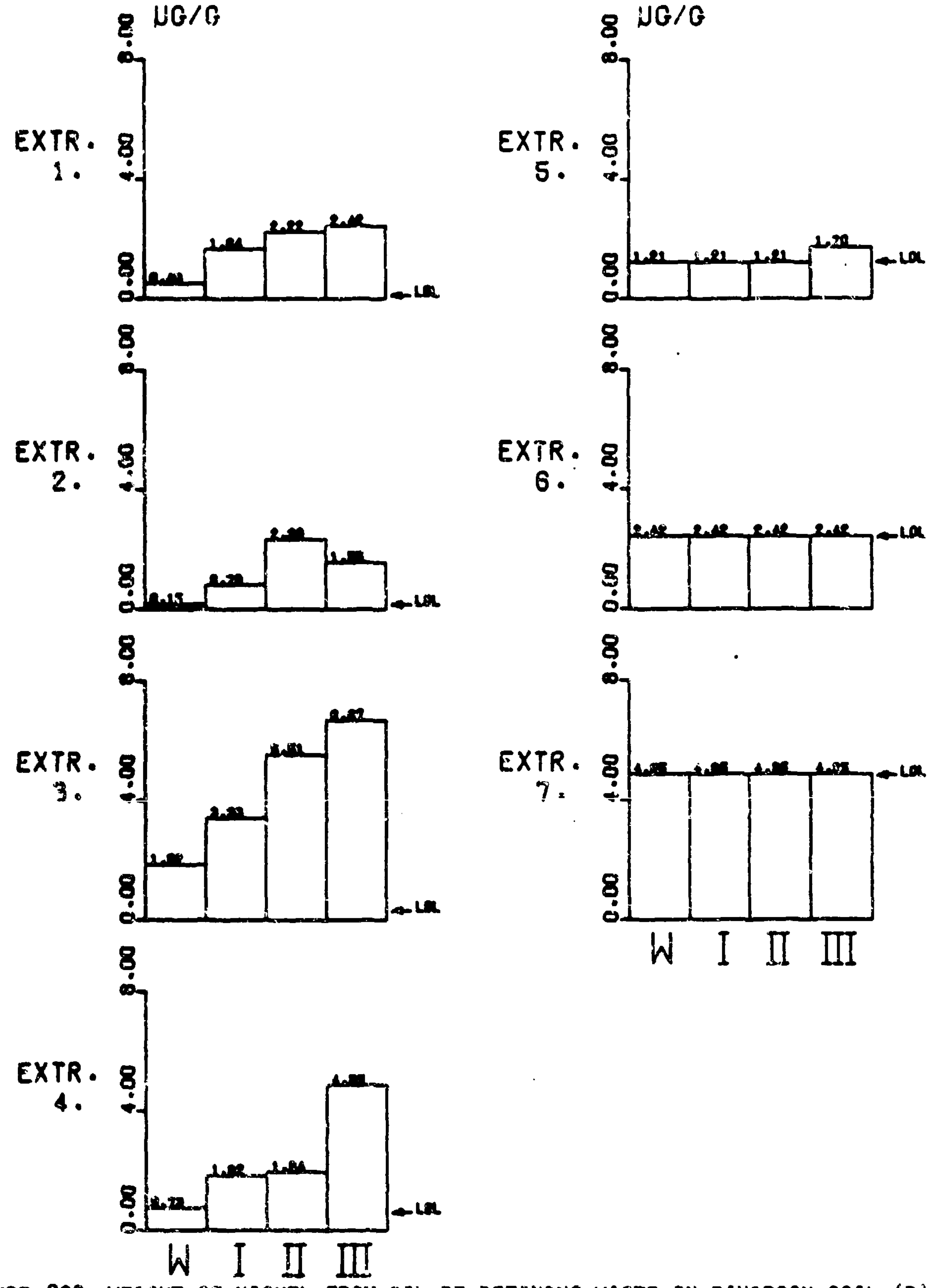


FIGURE 232. WEIGHT OF NICKEL FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 124. NICKEL FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.24	.40										
	I	2.53	5.05	-4.57	.40	-4.57	-9.42	-9.42	10.42	3.93	75.72	-.90	-42.11
	II	2.63	5.25	-.20	5.05	-.20	-.04	-.04	1.04	4.61	77.75	-.04	-2.20
	III	2.02	4.04	1.21	5.25	1.21	.23	.23	.77	6.34	81.04	.30	16.70
	I+II			-2.30	.24	-2.30	-9.83	-9.83	10.83	17.68	86.76	-.91	-42.23
	I+II+III			-1.19	.16	-1.19	-7.33	-7.33	8.33	53.48	88.93	-.88	-41.35
2	W	<.05	<.15										
	I	.93	2.79	-2.64	.64	-7.20	-17.46	-11.32	18.40	6.17	80.79	-2.56	-68.84
	II	1.72	5.15	-2.36	7.04	-2.57	-.05	-.33	1.05	4.24	76.73	-.50	-26.40
	III	1.72	5.15	.00	10.40	1.21	.00	.12	1.00	4.97	78.63	.24	13.24
	I+II			-2.50	.32	-4.00	-33.00	-15.35	34.00	17.05	86.64	-1.90	-62.19
	I+II+III			-1.67	.21	-2.85	-33.00	-13.44	34.00	40.97	88.60	-1.66	-58.95
3	W	.30	1.82										
	I	1.31	7.00	-6.06	2.45	-13.26	-3.33	-5.40	4.33	1.41	54.73	-1.68	-59.27
	II	2.42	14.54	-6.67	15.72	-9.23	-.85	-.59	1.85	1.04	46.20	-.63	-32.40
	III	2.53	15.15	-.61	24.95	.61	-.04	.02	1.04	1.65	58.79	.04	2.29
	I+II			-6.36	1.23	-11.25	-7.00	-9.16	8.00	5.16	79.04	-1.55	-57.11
	I+II+III			-4.44	.82	-7.30	-7.33	-8.92	8.33	13.05	85.62	-1.44	-55.31
4	W	.06	.73										
	I	.21	2.55	-1.82	3.18	-15.08	-2.50	-4.74	3.50	3.66	74.73	-5.92	-80.42
	II	.41	4.97	-2.42	18.26	-11.66	-.95	-.64	1.95	2.56	68.70	-2.35	-66.91
	III	1.01	12.12	-7.15	29.92	-6.54	-1.44	-.22	2.44	1.47	55.83	-.54	-28.37
	I+II			-2.12	1.59	-13.37	-5.83	-8.40	6.83	14.26	85.99	-5.38	-79.47
	I+II+III			-3.00	1.06	-11.09	-15.67	-10.46	16.67	15.37	86.28	-2.75	-69.99
5	W	<.05	<1.21										
	I	<.05	<1.21										
	II	.08	1.94										
	III	.12	2.91										
	I+II												
	I+II+III												
6	W	<.05	<2.42										
	I	<.05	<2.42										
	II	<.05	<2.42										
	III	<.05	<2.42										
	I+II												
	I+II+III												
7	W	<.05	<4.85										
	I	<.05	<4.85										
	II	<.05	<4.85										
	III	<.05	<4.85										
	I+II												
	I+II+III												

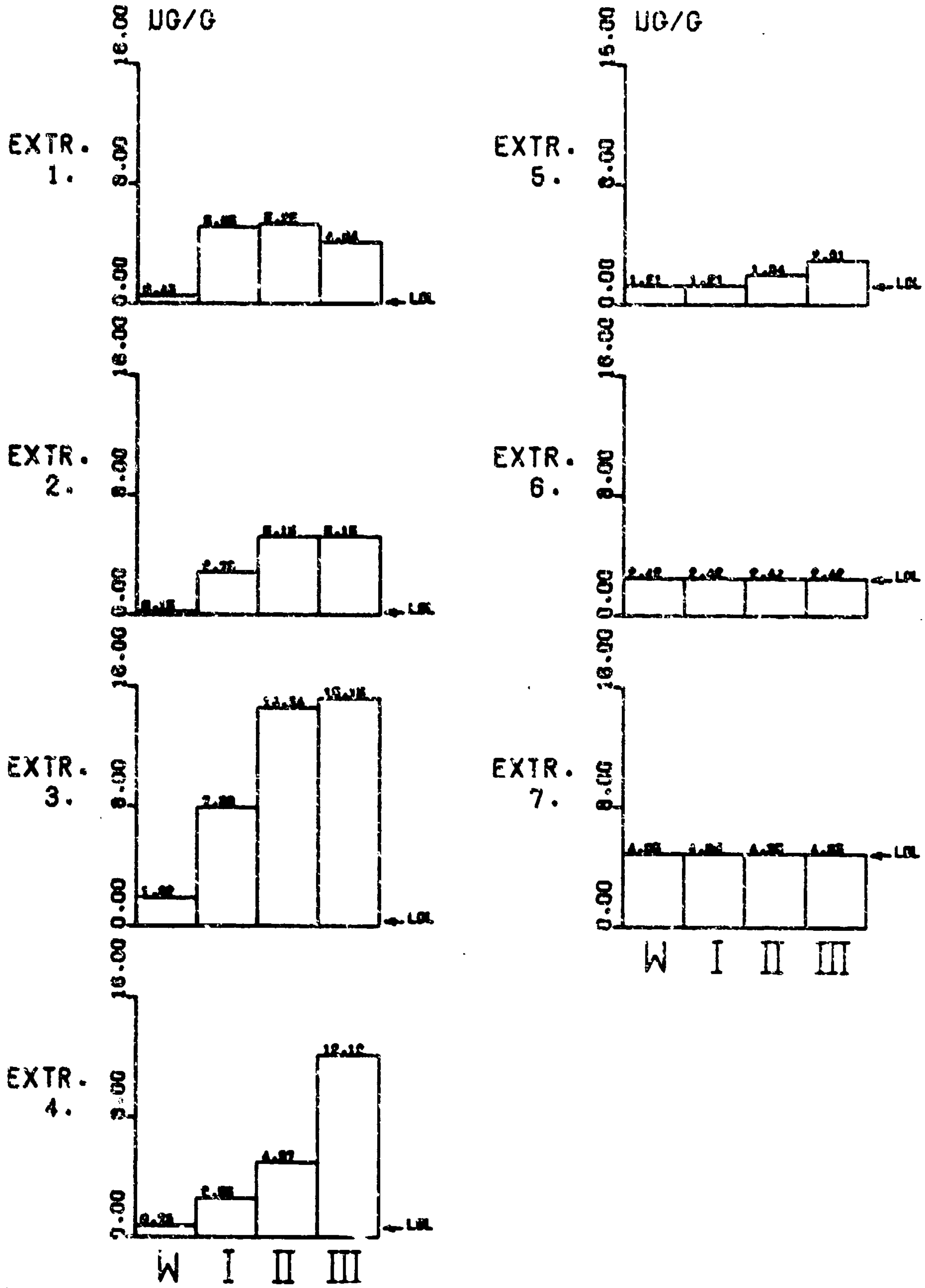


FIGURE 233. WEIGHT OF NICKEL FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

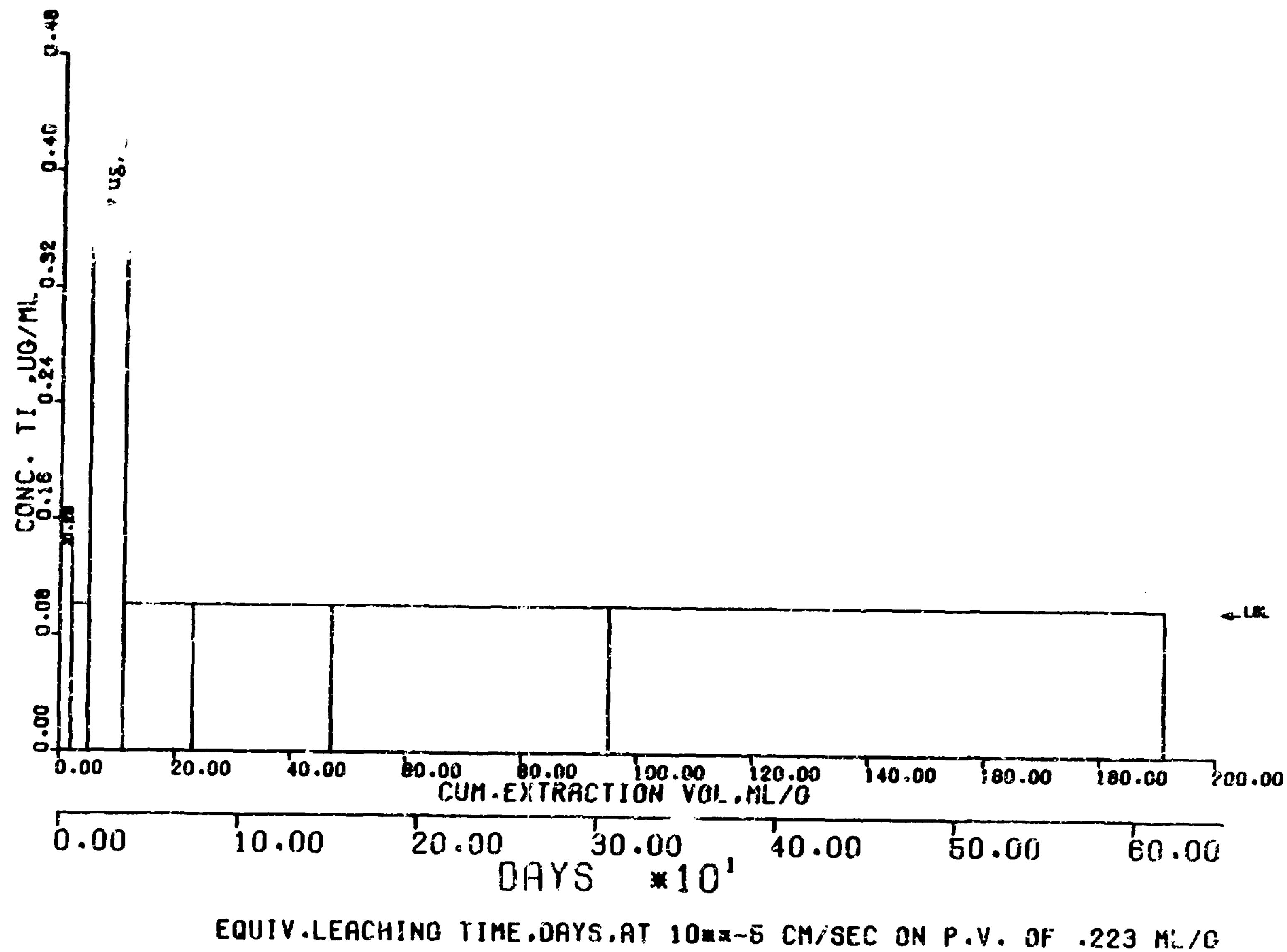


FIGURE 234. EXTRACTION OF TITANIUM FROM OIL RE-REFINING WASTE (B).

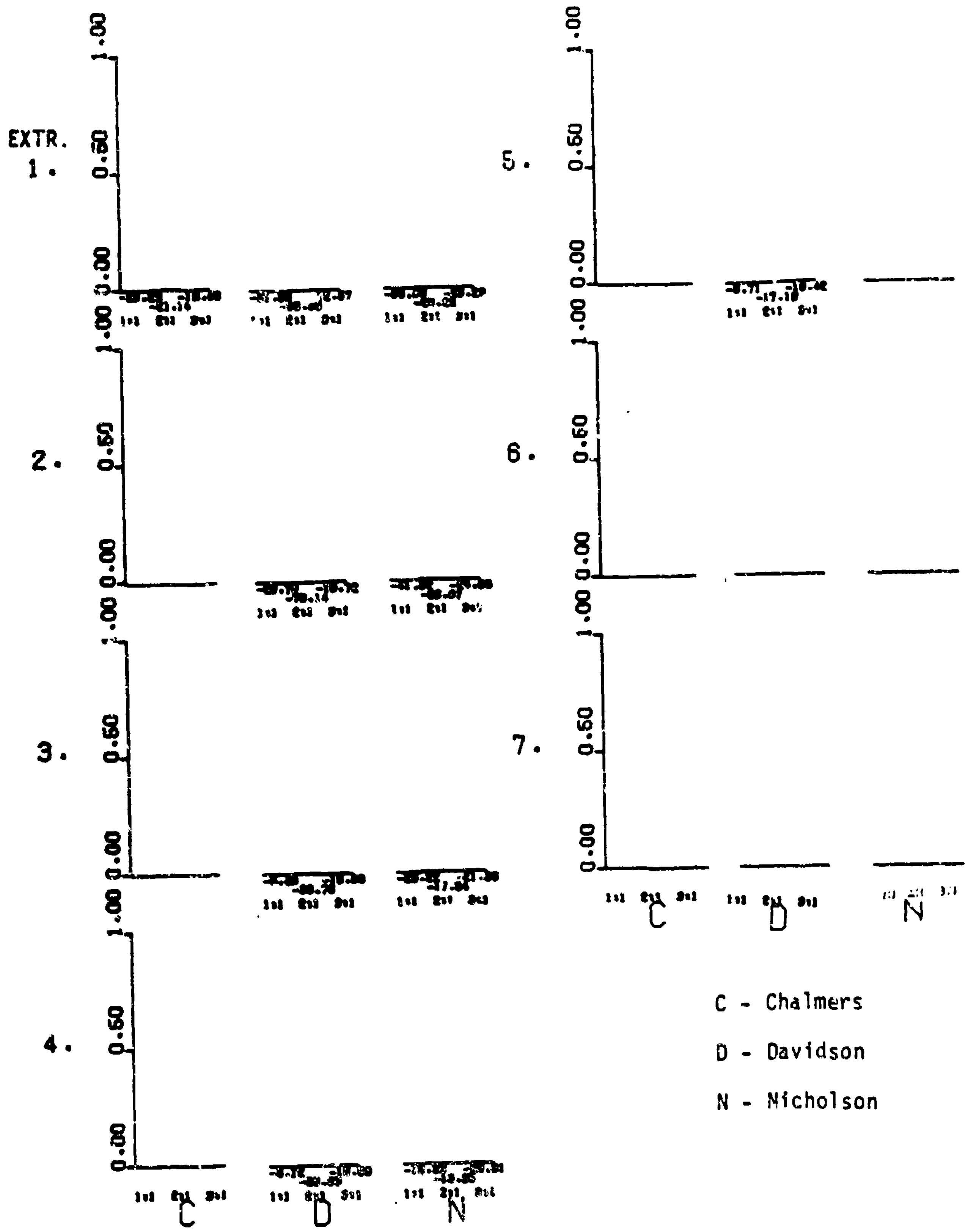


FIGURE 235. COMPARING FRACTION TITANIUM RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 125. TITANIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.14	.28										
	I	3.43	6.87	-6.59	.28	-6.59	-23.29	-23.29	24.29	14.18	85.97	-.96	-43.80
	II	3.13	6.26	.61	6.87	.61	.09	.09	.91	16.70	86.57	.10	5.53
	III	2.63	5.66	.61	6.26	.61	.10	.10	.90	10.49	86.91	.11	6.12
	I+II			-2.99	.14	-2.99	-21.14	-21.14	22.14	65.48	89.13	-.95	-43.68
	I+II+III			-1.79	.09	-1.79	-19.00	-19.00	20.00	164.54	89.65	-.95	-43.53
2	W	<.10	<.30										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	.35	2.12										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	<.10	<1.21										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	<.10	<2.42										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	<.10	<4.85										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	<.10	<9.79										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

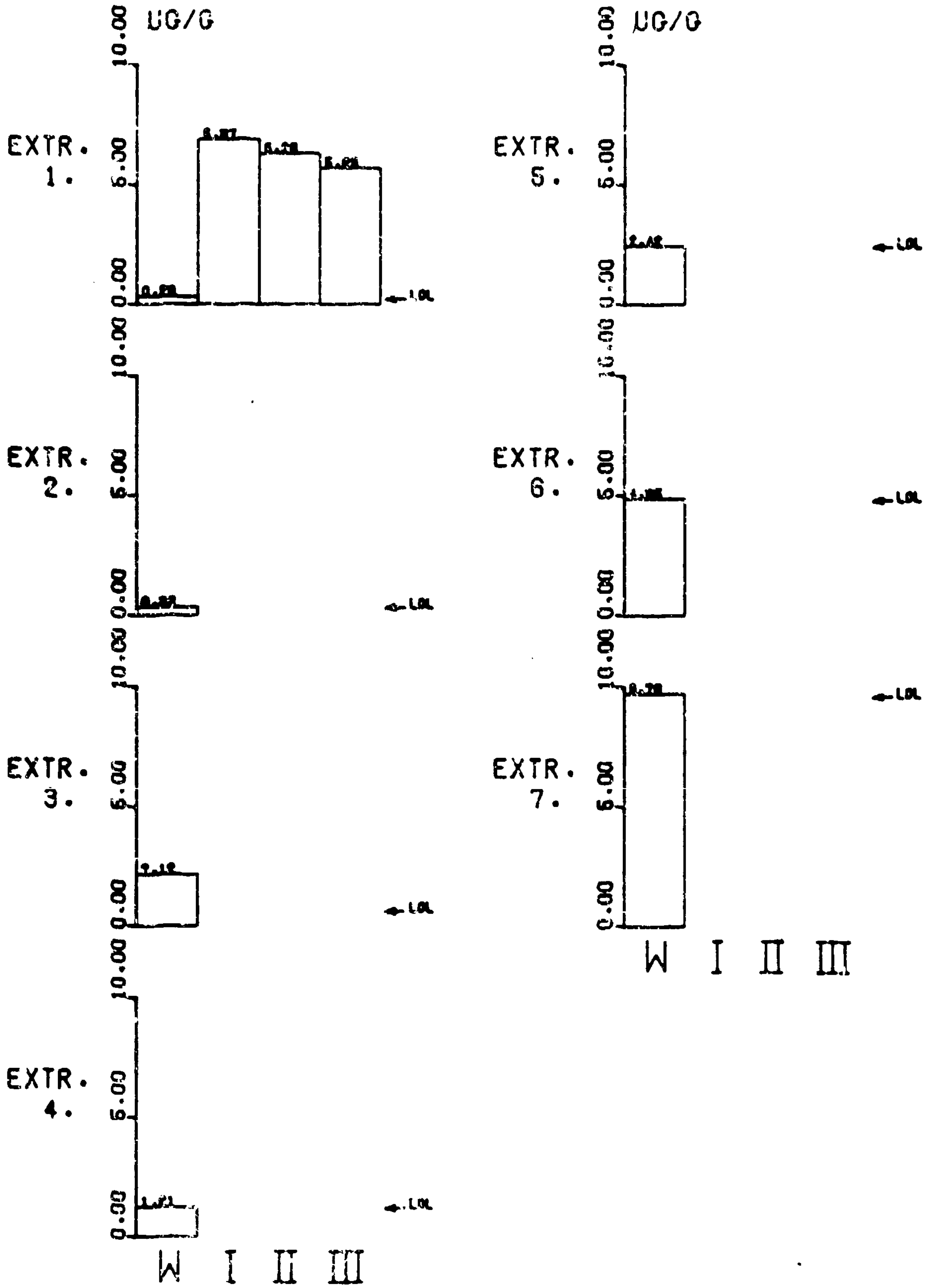


FIGURE 236. WEIGHT OF TITANIUM FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 126. TITANIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.14	.28										
	I	4.65	9.29	-9.01	.28	-9.01	-31.86	-31.86	32.86	139.80	89.59	-.97	-44.11
	II	5.35	10.71	-1.41	9.29	-1.41	-.15	-.15	1.15	122.04	89.53	-.13	-7.52
	III	1.92	3.84	6.87	10.71	6.87	.64	.64	.36	342.59	89.63	1.79	60.80
	I+II			-5.21	.14	-5.21	-36.86	-36.86	37.86	487.72	89.88	-.97	-44.23
	I+II+III			-1.19	.09	-1.19	-12.57	-12.57	13.57	3066.30	89.98	-.93	-42.81
2	W	.10	.30										
	I	2.32	6.97	-6.67	.59	-15.68	-22.00	-26.76	23.00	185.44	89.69	-2.25	-66.03
	II	10.91	32.72	-25.76	16.26	-27.17	-3.70	-1.67	4.70	39.14	88.54	-.83	-39.70
	III	1.01	3.03	29.69	43.43	36.56	.91	.84	.09	443.75	89.87	12.07	85.26
	I+II			-16.21	.29	-21.42	-107.00	-73.14	109.	158.57	89.64	-1.31	-52.63
	I+II+III			-.91	.20	-2.09	-9.00	-10.72	10.00	3883.00	89.99	-2.07	-64.25
3	W	.35	2.12										
	I	2.02	12.12	-10.00	2.71	-25.67	-4.71	-9.49	5.71	105.80	89.46	-2.12	-64.73
	II	9.80	58.78	-46.66	28.38	-73.83	-3.65	-2.60	4.85	21.00	87.27	-1.26	-51.47
	III	6.56	39.39	19.39	102.21	55.95	.33	.55	.67	34.63	88.35	1.42	54.86
	I+II			-28.33	1.35	-49.75	-26.71	-36.76	[illegible].71	87.31	89.34	-1.69	-59.43
	I+II+III			-12.42	.90	-14.52	-17.57	-16.09	18.57	297.75	89.81	-1.11	-47.87
4	W	<.10	<1.21										
	I	.94	11.27	-10.06	3.92	-35.73	-8.30	-9.12	9.30	112.87	89.49	-3.17	-72.49
	II	.59	7.03	4.24	39.65	-69.59	.38	-1.75	.62	176.17	89.67	-9.96	84.23
	III	1.92	23.03	-16.00	109.24	39.96	-2.28	.37	3.28	58.54	89.02	1.74	60.04
	I+II			-2.91	1.96	-52.66	-4.80	-26.88	5.80	729.30	89.92	-14.98	-86.18
	I+II+III			-7.27	1.31	-21.79	-18.00	-16.68	19.00	508.37	89.89	-2.84	-70.59
5	W	<.10	<2.42										
	I	.12	2.91	-.48	6.34	-36.22	-.20	-5.71	1.20	437.22	89.87	-12.45	-85.41
	II	.23	5.58	-2.67	42.56	-72.26	-.92	-1.70	1.92	221.65	89.74	-12.96	-85.59
	III	.13	3.15	2.42	114.82	42.38	.43	.37	.57	428.53	89.87	13.45	85.75
	I+II			-1.58	3.17	-54.24	-1.30	-17.10	2.30	918.99	89.94	-19.46	-87.06
	I+II+III			-.24	2.11	-22.03	-.30	-10.42	1.30	3714.75	89.98	-20.97	-87.27
6	W	<.10	<4.85										
	I	<.10	<4.65										
	II	<.10	<4.85										
	III	<.10	<4.85										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	<.10	<9.70										
	II	<.10	<9.70										
	III	<.10	<9.70										
	I+II												
	I+II+III												

The remainder of the table was not calculated because the concentrations were below the detection limit.

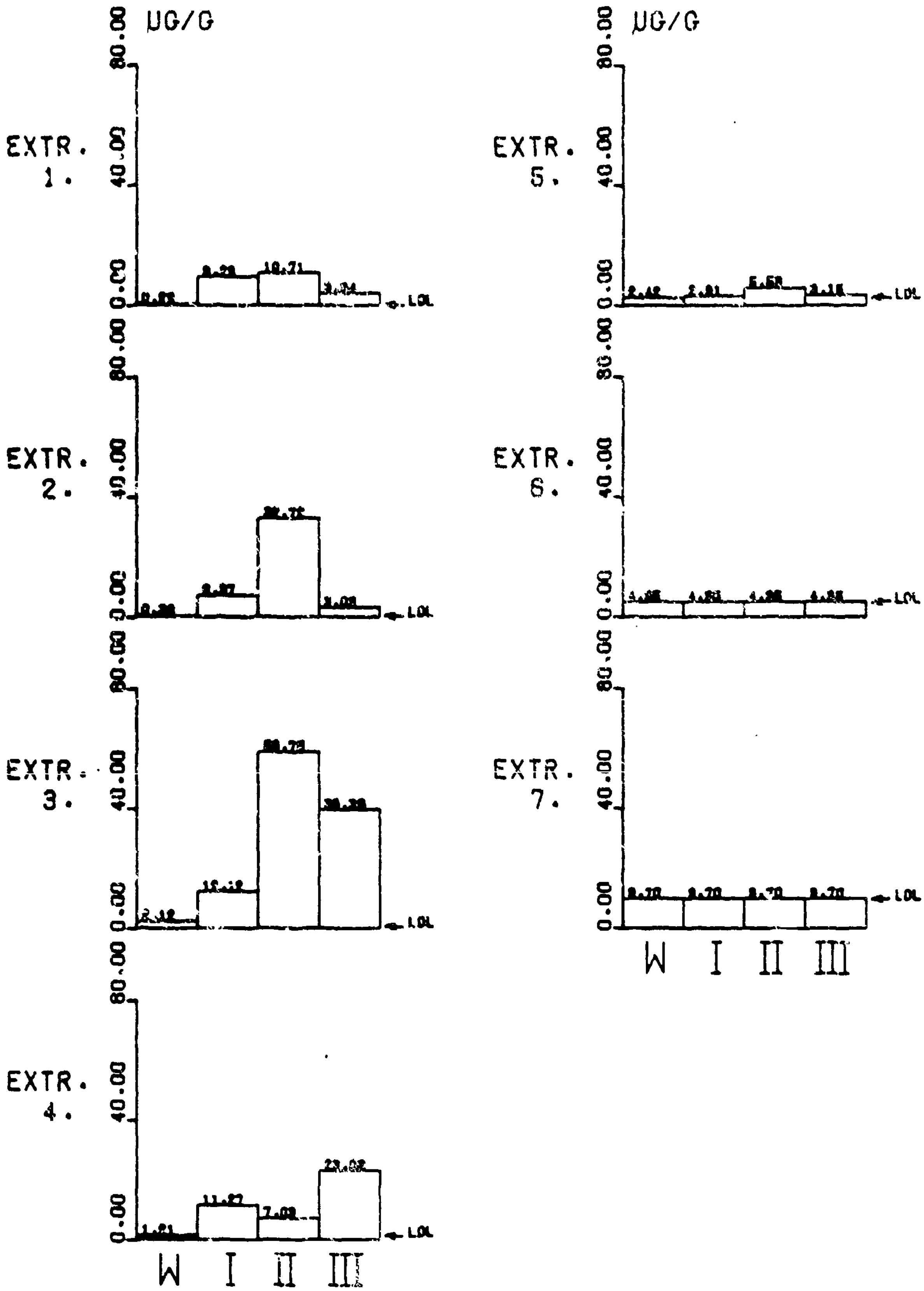


FIGURE 237. WEIGHT OF TITANIUM FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 127. TITANIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	.14	.28										
	I	9.90	19.80	-19.51	.28	-19.51	-67.00	-69.00	70.00	4.90	78.63	-.99	-44.59
	II	4.14	8.20	11.51	19.80	11.51	.58	.50	.42	15.64	86.34	1.39	54.27
	III	3.43	6.87	1.41	8.20	1.41	.17	.17	.83	17.39	86.71	.21	11.63
	I+II			-4.00	.14	-4.00	-28.29	-28.29	29.29	56.03	88.98	-.97	-44.00
	I+II+III			-2.20	.09	-2.20	-23.29	-23.29	24.29	153.67	89.63	-.96	-43.80
2	W	<.10	<.30										
	I	1.72	5.15	-4.85	.59	-24.36	-16.00	-41.59	17.00	10.12	86.85	-4.73	-78.06
	II	2.53	7.58	-2.42	24.95	9.09	-.47	.36	1.47	16.78	86.59	1.20	50.19
	III	2.73	8.18	-.61	15.06	.81	-.08	.05	1.08	14.52	86.06	.10	5.64
	I+II			-3.64	.29	-7.64	-24.00	-26.07	25.00	60.29	89.05	-2.02	-63.62
	I+II+III			-2.63	.20	-4.82	-26.00	-24.69	27.00	128.05	89.55	-1.77	-60.51
3	W	.35	2.12										
	I	6.77	40.60	-38.48	2.71	-62.84	-18.14	-23.22	19.14	1.36	53.64	-1.55	-57.13
	II	5.86	35.15	5.45	65.55	14.54	.13	.22	.87	3.77	75.15	.41	22.48
	III	7.57	45.45	-10.30	51.01	-9.49	-.29	-.19	1.29	2.39	67.27	-.21	-11.80
	I+II			-16.51	1.35	-24.15	-15.57	-17.84	16.57	12.05	85.26	-1.37	-53.96
	I+II+III			-14.44	.90	-19.26	-20.43	-21.35	21.43	22.09	87.41	-1.27	-51.82
4	W	<.10	<1.21										
	I	.25	3.03	-1.82	3.92	-64.66	-1.50	[illegible]	2.50	17.60	86.75	-21.34	-87.32
	II	.40	4.85	-1.32	68.58	12.73	-.60	.19	1.60	26.96	87.88	2.63	69.15
	III	1.82	21.82	-16.97	55.85	-26.46	-3.50	-.47	4.50	4.20	76.59	-1.21	-50.50
	I+II			-1.82	1.96	-25.97	-3.00	-13.25	4.00	86.65	89.34	-10.71	-84.67
	I+II+III			-6.97	1.31	-26.13	-17.00	-20.01	18.00	45.09	88.73	-3.59	-74.45
5	W	<.10	<2.42										
	I	<.10	<2.42										
	II	.11	2.67										
	III	<.10	<2.42										
	I+II												
	I+II+III												
6	W	<.10	<4.85										
	I	<.10	<4.35										
	II	<.10	<4.85										
	III	<.10	<4.85										
	I+II												
	I+II+III												
7	W	<.10	<9.70										
	I	<.10	<9.70										
	II	<.10	<9.70										
	III	<.10	<9.70										
	I+II												
	I+II+III												

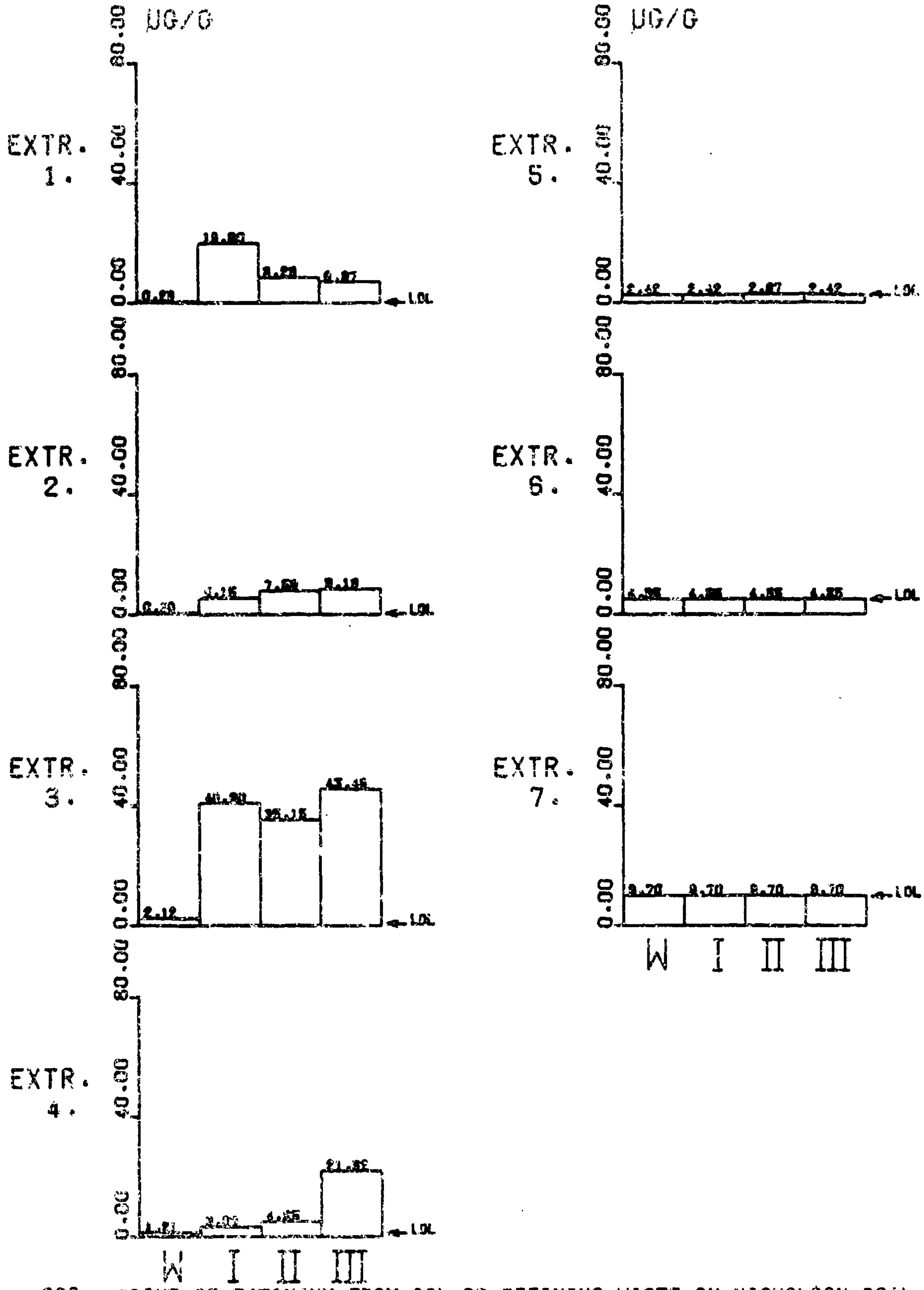


FIGURE 238. WEIGHT OF TITANIUM FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

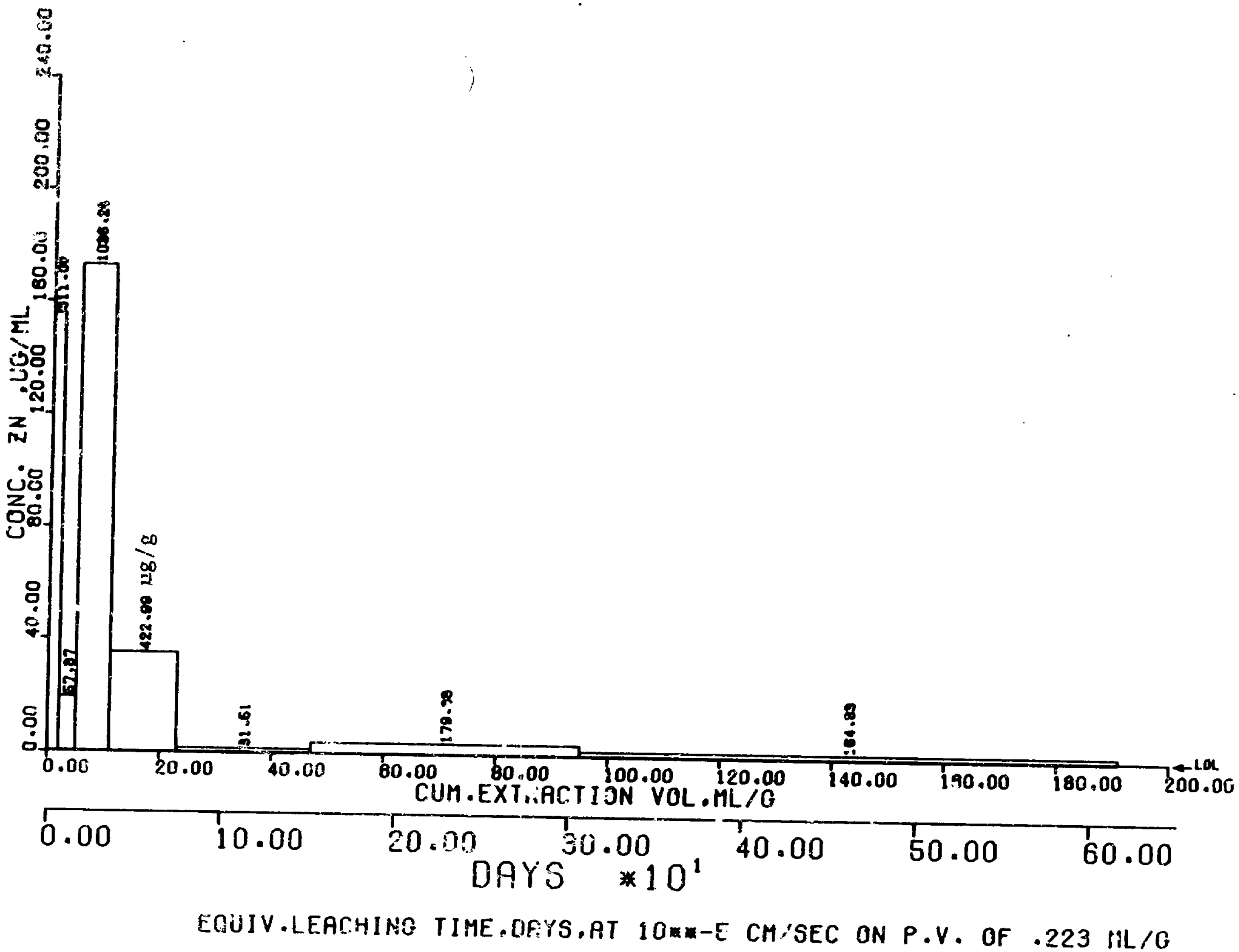


FIGURE 239. EXTRACTION OF ZINC FROM OIL RE-REFINING WASTE (B).

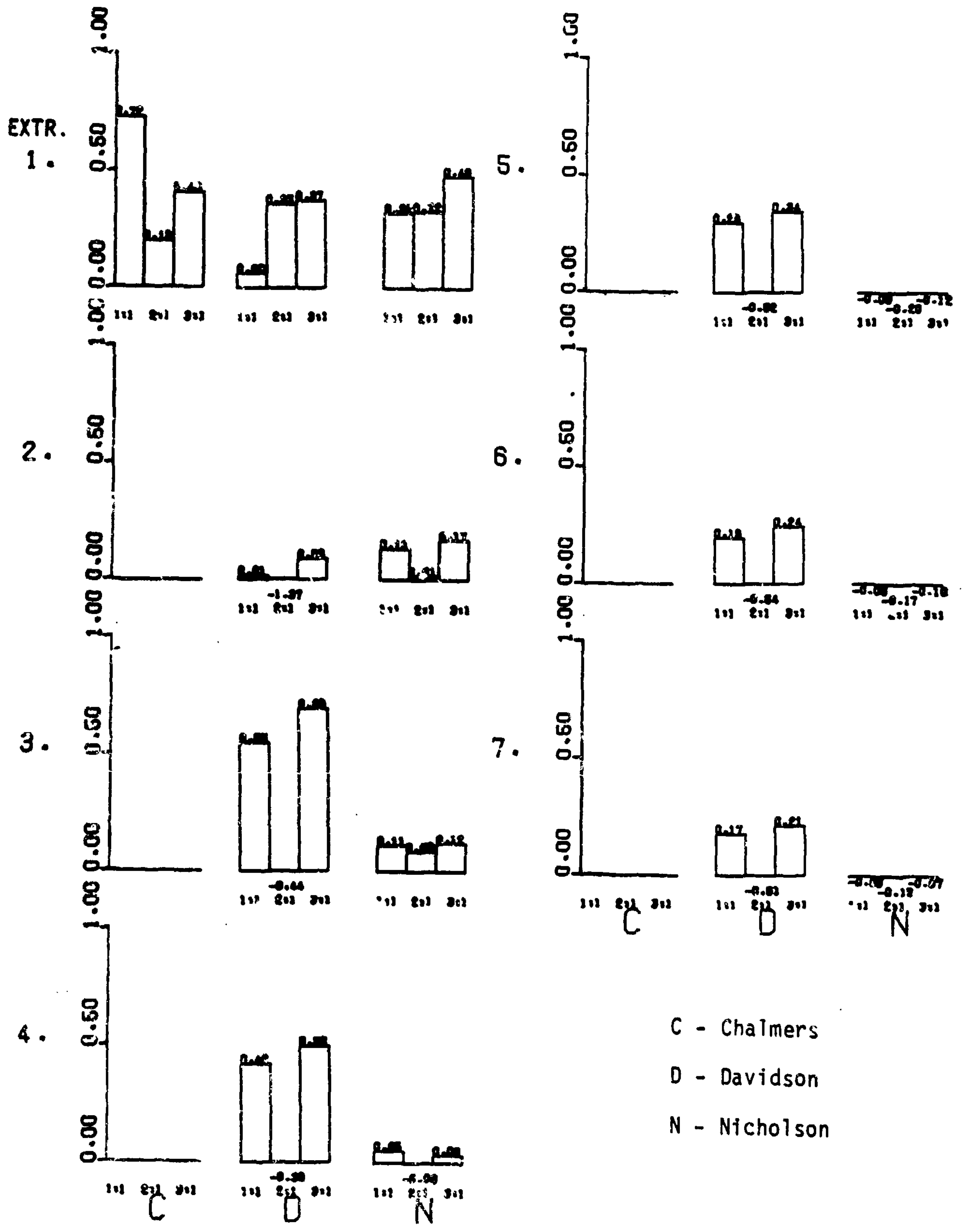


FIGURE 240. COMPARING FRACTION ZINC RETAINED BY SOILS FROM OIL RE-REFINING WASTE LEACHATE (B).

TABLE 128. ZINC FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

EXT. NR.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL. SOIL RATIO	DISTRIBUTION COEFFICIENTS INCL. SOIL DEG.	DISTRIBUTION COEFFICIENTS SOLN ONLY RATIO	DISTRIBUTION COEFFICIENTS SOLN ONLY DEG.
1	W	155.54	311.08										
	I	42.93	85.85	225.23	311.08	225.23	.72	.72	.28	3.34	73.35	2.62	69.13
	II	125.24	250.48	-164.63	85.65	-164.63	-1.92	-1.92	2.92	-.41	-22.32	-.66	-33.32
	III	93.02	186.04	64.44	250.48	64.44	.26	.26	.74	.68	34.16	.35	19.10
	I+II			30.30	155.54	30.30	.19	.19	.81	1.23	58.86	.24	13.60
	I+II+III			41.68	103.69	41.68	.40	.40	.60	3.66	74.73	.67	33.90
2	W	19.29	57.87										
	I												
	II												
	III												
	I+II												
	I+II+III												
3	W	172.71	1036.26										
	I												
	II												
	III												
	I+II												
	I+II+III												
4	W	35.25	422.99										
	I												
	II												
	III												
	I+II												
	I+II+III												
5	W	1.31	31.51										
	I												
	II												
	III												
	I+II												
	I+II+III												
6	W	3.74	179.38										
	I												
	II												
	III												
	I+II												
	I+II+III												
7	W	1.72	164.83										
	I												
	II												
	III												
	I+II												
	I+II+III												

This experiment terminated after the first extraction of Chalmers soil.

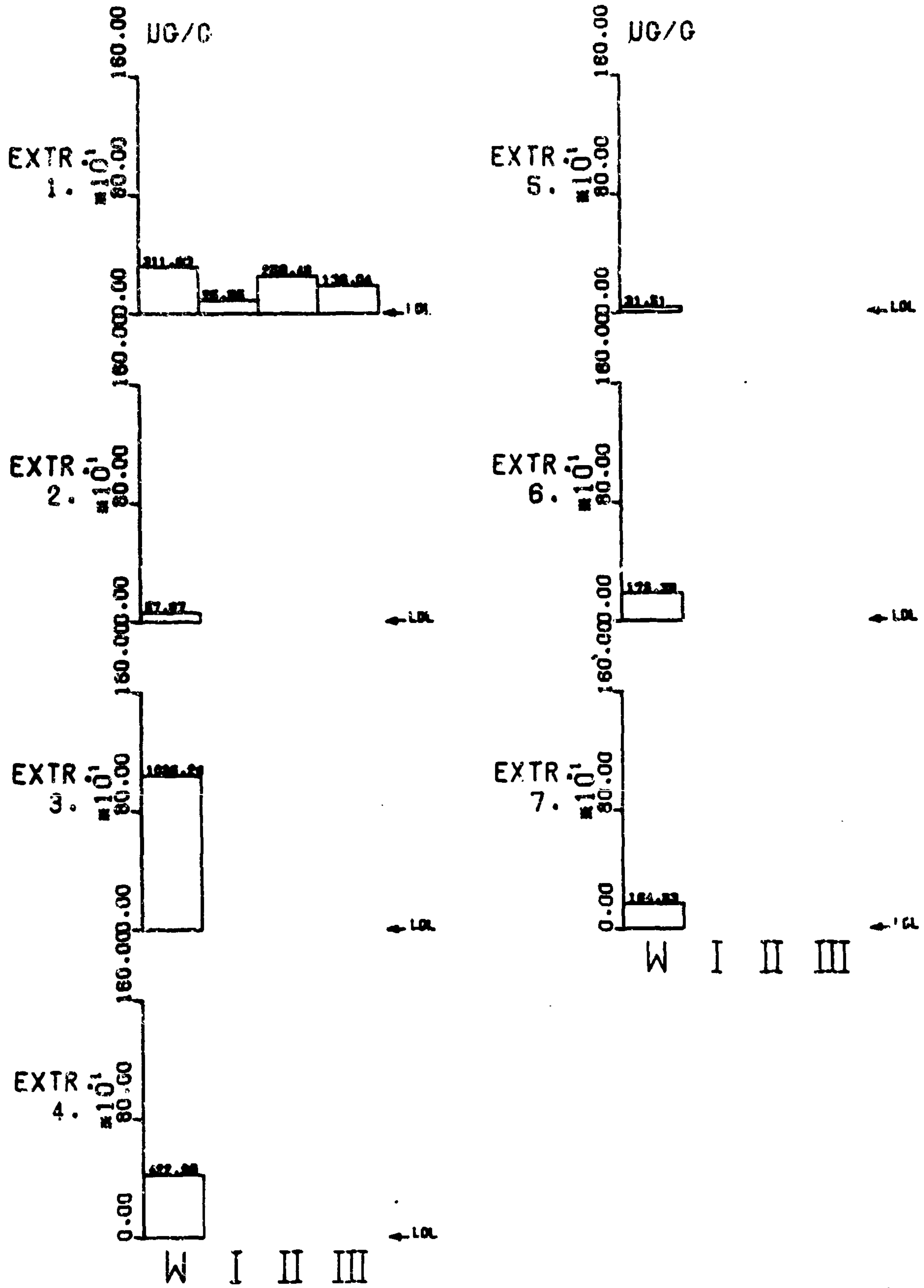


FIGURE 241. WEIGHT OF ZINC FROM OIL RE-REFINING WASTE ON CHALMERS SOIL (B).

TABLE 129. ZINC FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

EXT. NR.	LAYER	AMT. PENETR. UG/ML	AMT. PENETR. UG/G	AMT. RETD. THIS EXT. UG/G	CUM. TOT. CHALLG. UG/G	CUM. TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	155.54	311.08										
	I	146.45	292.90	18.18	311.08	18.18	.06	.06	.94	.25	14.03	.06	3.55
	II	100.39	200.79	92.11	292.90	92.11	.31	.31	.69	.73	36.23	.46	24.64
	III	97.97	195.94	4.85	200.79	4.85	.02	.02	.98	.31	16.98	.02	1.42
	I+II			55.15	155.54	55.15	.35	.35	.65	1.64	58.70	.55	28.70
	I+II+III			38.38	103.69	38.38	.37	.37	.63	3.11	72.20	.59	30.44
2	W	19.29	57.87										
	I	23.74	71.21	-13.33	368.95	4.85	-.23	.01	1.23	.84	40.05	.07	3.89
	II	224.22	672.66	-601.46	364.11	-509.34	-8.45	-1.40	9.45	-.68	-34.04	-.76	-37.13
	III	47.17	141.50	531.16	873.45	536.01	.79	.61	.21	4.18	76.54	3.79	75.21
	I+II			-307.39	184.48	-252.25	-10.62	-1.37	11.62	-.42	-22.93	-.75	-36.87
	I+II+III			-27.88	122.98	10.50	-1.45	.09	2.45	3.72	74.96	.22	12.55
3	W	172.71	1036.26										
	I	45.65	273.91	762.35	1465.21	767.20	.74	.55	.26	3.00	71.57	2.80	70.35
	II	191.90	1151.40	-877.49	638.02	-1386.83	-3.20	-2.17	4.20	-1.16	-49.16	-1.20	-50.38
	III	15.45	92.72	1058.68	2024.85	1594.69	.92	.79	.08	17.79	86.78	17.20	86.67
	I+II			-57.57	702.61	-309.82	-.11	-.44	1.11	-.35	-19.14	-.54	-28.29
	I+II+III			314.51	468.40	325.02	.91	.69	.09	15.86	86.39	16.52	84.57
4	W	35.25	422.99										
	I	35.55	426.62	-3.64	1828.20	763.56	-.01	.42	1.01	1.92	62.47	1.79	60.81
	II	42.82	513.89	-87.26	1064.64	-1474.09	-.20	-1.38	1.20	-2.76	-70.09	-2.87	-70.78
	III	40.90	490.86	23.03	2538.74	1617.72	.04	.64	.96	3.41	73.65	3.30	73.12
	I+II			-45.45	914.10	-355.27	-.21	-.39	1.21	-.95	-43.67	-1.38	-54.12
	I+II+III			-22.62	609.40	302.39	-.16	.50	1.16	2.86	70.71	1.85	61.58
5	W	1.31	31.51										
	I	10.30	247.25	-215.74	1859.71	547.82	-6.85	.29	7.85	2.44	67.70	2.22	65.71
	II	12.32	295.73	-48.48	1311.89	-1522.57	-.20	-1.16	1.20	-4.96	-78.61	-5.15	-79.01
	III	12.63	303.00	-7.27	2834.46	1610.45	-.02	.57	1.02	5.50	79.69	5.32	79.34
	I+II			-132.11	929.86	-487.38	-8.38	-.52	9.38	-2.55	-68.60	-3.30	-73.12
	I+II+III			-90.50	619.90	211.90	-8.62	.34	9.62	3.73	75.00	2.10	64.52
6	W	3.74	179.38										
	I	6.97	334.51	-155.14	2039.09	392.69	-.86	.19	1.86	1.34	53.23	1.17	49.57
	II	6.46	310.27	24.24	1545.40	-1498.33	.07	-.91	.93	-4.65	-77.87	-4.83	-78.30
	III	6.77	324.82	-14.54	3144.74	1595.90	-.05	.51	1.05	5.08	78.87	4.91	78.50
	I+II			-65.45	1019.54	-552.62	-.73	-.54	1.73	-2.85	-70.69	-3.56	-74.32
	I+II+III			-48.48	679.70	163.42	-.81	.24	1.81	3.03	71.75	1.51	56.47
7	W	1.72	164.83										
	I	1.82	174.53	-9.70	2203.92	382.99	-.06	.17	1.06	2.51	68.27	2.19	65.50
	II	2.02	193.92	-19.39	1820.93	-1517.73	-.11	-.83	1.11	-7.54	-82.45	-7.83	-82.72
	III	2.02	193.92	.00	3338.66	1595.90	.00	.48	1.00	8.51	83.30	8.23	83.07
	I+II			-14.54	1101.96	-567.37	-.18	-.51	1.18	-4.72	-78.03	-5.85	-80.30
	I+II+III			-9.70	734.64	153.72	-.18	.21	1.18	4.93	78.54	2.38	67.19

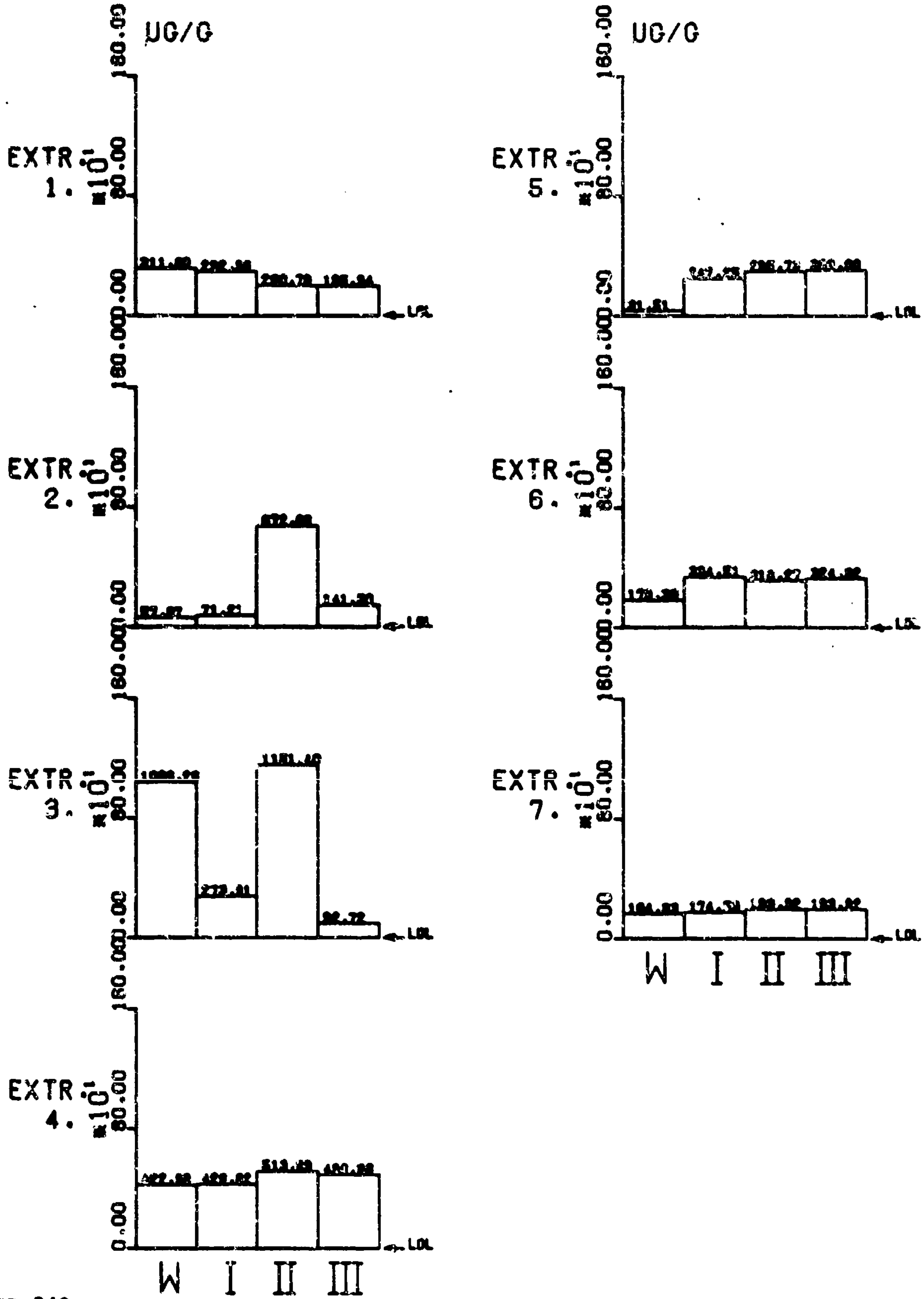


FIGURE 242. WEIGHT OF ZINC FROM OIL RE-REFINING WASTE ON DAVIDSON SOIL (B).

TABLE 130. ZINC FROM OIL RE-REFINING WASTE ON NICHOLSON (B).

EXT. NO.	LAYER	AMT.PENETR. UG/ML	AMT.PENETR. UG/G	AMT.RETD. THIS EXT. UG/G	CUM.TOT. CHALLG. UG/G	CUM.TOT. RETD. UG/G	FRACTION RETD. THIS EXTR.	FRACTION RETD. TOTAL CHALLG.	PENETR. FACTOR	DISTRIBUTION COEFFICIENTS INCL SOIL RATIO	INCL SOIL DEG.	SOLN ONLY RATIO	SOLN ONLY DEG.
1	W	155.54	311.08										
	I	106.05	212.10	98.98	311.08	98.98	.32	.32	.68	.82	39.33	.47	25.02
	II	105.04	210.08	2.02	212.10	2.02	.01	.01	.99	.37	20.09	.01	.55
	III	81.41	162.81	47.27	210.08	47.27	.22	.22	.78	.75	36.86	.29	16.19
	I+II			50.50	155.54	50.50	.32	.32	.68	1.90	62.30	.48	25.68
	I+II+III			49.42	103.69	49.42	.48	.48	.52	5.05	78.79	.91	42.32
2	W	19.29	57.87										
	I	36.46	109.38	-51.51	368.95	47.47	-.89	.13	1.89	1.12	48.18	.43	23.46
	II	51.21	153.62	-44.24	321.48	-42.22	-.40	-.13	1.40	.21	11.97	-.27	-15.37
	III	48.08	144.23	9.39	363.70	56.66	.06	.16	.94	.91	42.35	.39	21.45
	I+II			-47.87	184.48	2.63	-1.65	.01	2.65	1.98	63.23	.03	1.96
	I+II+III			-28.79	122.98	20.64	-1.49	.17	2.49	5.10	78.90	.43	23.23
3	W	172.71	1036.26										
	I	155.54	933.24	103.02	1405.21	150.49	.10	.11	.90	.24	13.57	.16	9.16
	II	154.53	927.18	6.06	1254.72	-36.16	.01	-.03	.99	.04	2.39	-.04	-2.23
	III	155.54	933.24	-6.06	1290.88	50.60	-.01	.04	1.01	.13	7.65	.05	3.10
	I+II			54.54	702.61	57.17	.11	.08	.89	.45	24.04	.12	7.03
	I+II+III			34.34	468.40	54.98	.10	.12	.90	.90	41.93	.18	10.02
4	W	35.25	422.99										
	I	40.50	486.01	-63.02	1828.20	87.47	-.15	.05	1.15	.33	18.46	.18	10.20
	II	54.14	649.63	-163.62	1740.74	-199.78	-.34	-.11	1.34	-.19	-10.89	-.31	-17.09
	III	44.24	530.86	118.78	1940.51	169.38	.18	.09	.82	.46	24.70	.32	17.70
	I+II			-113.32	914.10	-56.16	-.54	-.06	1.54	.29	16.05	-.17	-9.81
	I+II+III			-35.96	609.40	19.02	-.26	.03	1.26	1.33	53.99	.11	6.14
5	W	1.31	31.51										
	I	11.01	264.22	-232.71	1859.71	-145.24	-7.38	-.08	8.38	-.27	-14.93	-.55	-28.80
	II	11.92	286.03	-21.82	2004.95	-221.59	-.08	-.11	1.08	-.51	-27.17	-.77	-37.77
	III	13.23	317.54	-31.51	2226.55	137.86	-.11	.06	1.11	.67	33.81	.43	23.47
	I+II			-127.26	929.86	-183.42	-8.08	-.20	9.08	-.24	-13.30	-1.28	-52.06
	I+II+III			-95.34	619.90	-76.32	-9.08	-.12	10.08	1.40	54.44	-.72	-35.79
6	W	3.74	179.38										
	I	3.23	155.14	24.24	2039.09	-121.00	.14	-.06	.86	-.30	-16.58	-.78	-37.95
	II	3.33	159.98	-4.85	2160.09	-226.44	-.03	-.10	1.03	-.95	-43.47	-1.42	-54.76
	III	3.03	145.44	14.54	2386.53	152.41	.09	.06	.91	1.56	57.38	1.05	46.34
	I+II			9.70	1019.54	-173.72	.11	-.17	.89	-.30	-16.78	-2.17	-65.28
	I+II+III			11.31	679.70	-65.01	.19	-.10	.81	3.29	73.08	-1.34	-53.29
7	W	1.72	164.83										
	I	1.92	184.22	-19.39	2203.92	-140.39	-.12	-.06	1.12	-.36	-19.60	-.76	-37.31
	II	1.62	155.14	29.09	2344.31	-197.35	.16	-.08	.84	-.79	-38.31	-1.27	-51.83
	III	1.31	126.05	29.09	2541.67	181.50	.19	.07	.81	2.03	63.81	1.44	55.22
	I+II			4.85	1101.96	-168.87	.06	-.15	[illegible]	-.25	-13.95	-2.18	-65.33
	I+II+III			12.93	734.64	-52.08	.24	-.07	.76	4.10	76.30	-1.24	-51.11

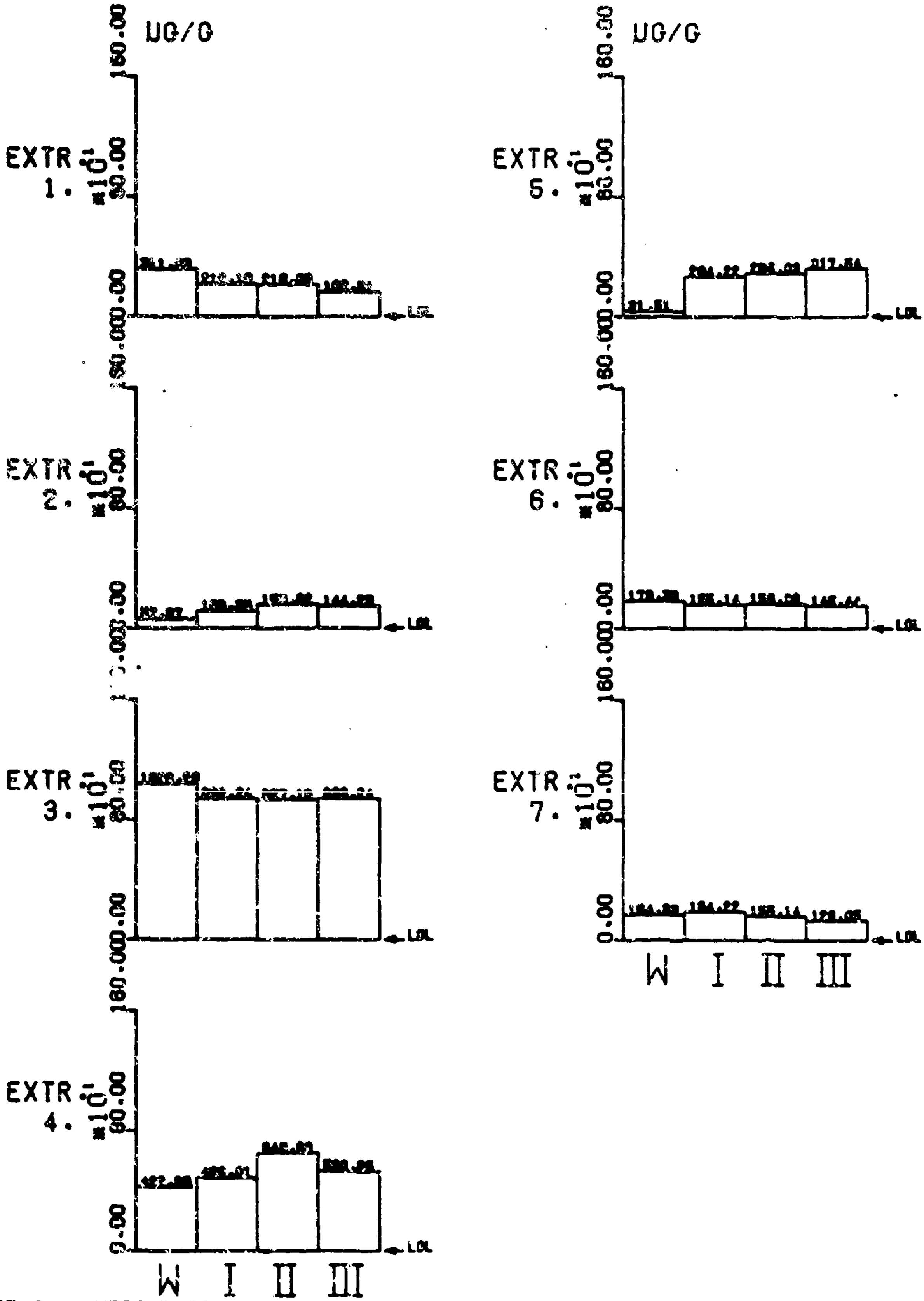


FIGURE 243. WEIGHT OF ZINC FROM OIL RE-REFINING WASTE ON NICHOLSON SOIL (B).

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APPENDIX A

CORRELATION BETWEEN CUMULATIVE EXTRACTION VOLUME AND PENETRATION TIME AT DARCIAN VELOCITIES

Table A-1 is similar to Table 12, page 37, except that Darcian velocities are given instead of pore water velocities. Equation 14, page 36, was used to prepare this example.

TABLE A-1. CORRELATION BETWEEN EXTRACTION VOLUME AND PENETRATION TIME

Extraction Number	Water Added, (mL/g)	Cumul. Vol., (mL/g)	Equivalent Days of Penetration[a] @10^{-5} cm/sec	@10^{-6} cm/sec	@10^{-7} cm/sec
1	2	2	2.3	23.	231. (0.63 yr)
2	3	5	5.8	57.	578. (1.6 yr)
3	6	11	12.7	127. (0.35 yr)	1273. (3.5 yr)
4	12	23	26.6	266. (0.73 yr)	2262. (7.3 yr)
5	24	47	54.4	544. (1.5 yr)	5440. (15 yr)
6	48	95	110. (0.3 yr)	1100. (3.0 yr)	10995. (30 yr)
7	96	191	221. (0.6 yr)	2210. (6.1 yr)	22106. (61 yr)

[a] At the specified Darcian velocity.

APPENDIX B

SHOWING CONCENTRATION AS A FUNCTION OF SOIL DEPTH AS THE WASTE EXTRACTION PROGRESSES

Table B-1 is a way of presenting the raw data that shows the concentration (both micrograms/milliliter and micrograms/gram) in the solution within the soil at every stage of the serial batch extraction of a waste; the field of data gives a visual impression of the effects of depth and leaching time or volume. Studying this table to draw conclusions about the onset of release of an element from the soil is best done with the assistance of the tabulated calculations of amounts, cumulative totals, and fractions retained, as given in Tables 63 and 66.

TABLE B-1. CONCENTRATIONS OF SELECTED ELEMENTS IN SOLUTIONS FROM ZINC SECONDARY-REFINING SLUDGE ON CHALMERS SOIL

		Equivalent Time, Days of Penetration, at 10^{-3}cm/sec Pore Water Velocity														Soil to Waste Ratio
		6.5		16.2		35.6		74.5		152		308		619		
		Cumulative Extraction Volume, ml/g														
Element	Layer	2		5		11		23		47		95		191		
		μg/ml	μg/g	μg/ml	μg/g	μg/ml	μg/g	μg/ml	μg/g	μg/ml	μg/g	μg/ml	μg/g	μg/ml	μg/g	
Cadmium																
	W	116.	232.	34.	101.	5.7	34.	1.5	18.	0.34	8.1	0.22	10.	0.08	7.3	
	I	54.	107.	28.	83.	5.2	31.	2.4	28.	0.80	19.	1.3	61.	1.1	107.	1:1
	II	17.	33.	12.	34.	5.2	32.	1.3	16.	0.60	14.	1.4	68.	1.0	97.	1:2
	III	3.	6.	5.9	18.	1.8	11.	.71	8.5	0.25	6.1	0.25	12.	0.83	80.	1:3
Lead																
	W	9.5	19.	7.6	23.	6.4	38.	4.9	58.	9.2	220.	9.6	459.	7.5	721.	
	I	0.73	1.5	0.85	2.6	0.64	3.9	0.20	2.4	0.26	6.2	0.67	32.	0.57	55.	1:1
	II	1.5	3.0	0.35	1.0	0.29	1.8	0.58	7.0	0.10	2.4	0.50	24.	0.17	16.	1:2
	III	0.7	1.4	0.89	2.7	0.53	3.2	0.16	1.9	0.74	17.8	0.23	11.	0.12	12.	1:3

APPENDIX C

RESULTS OF PUTTING WATER ON SOILS PREVIOUSLY EXPOSED TO WASTE LEACHATE

SOILS LEFT FROM SERIAL BATCH EXTRACTION EXPERIMENTS

Batches of soil that had been exposed to a series of seven extractions of waste (as described in the body of this report) were saved and one of the sets (from the duplicates) was extracted with water. Batch I of each "old" soil was first extracted with 2 milliliters of water per gram. After periodic shaking, the soil was filtered 24 hours later and the filtrate was used to extract soil batch II. Batch I was again extracted, this time by 3 milliliters of water per gram, then by 6, and finally by 12 milliliters per gram. The filtrates from these were used as the challenges to soil batches II and III, each in turn (except that only one batch of soil was challenged by zinc-carbon battery waste). The results of analyzing aliquots from these samples are presented in Tables C-1 through C-3 for zinc-carbon battery waste and in Tables C-4 through C-6 for titanium dioxide pigment production waste.

SOILS LEFT FROM SOIL CAPACITY EXPERIMENTS

Preliminary experiments had been run to determine the capacity that these clay soils have for holding hazardous ions from waste leachates. In those experiments, samples of the soils were challenged repeatedly by waste leachate. First, a large quantity of waste leachate was prepared by extracting a waste with 2 milliliters of water per gram of waste. Then aliquots of this extract were placed on a soil in the proportion of 2 milliliters of waste leachate per gram of soil. After 24 hours, the soil was filtered and another 2 milliliters of leachate per gram was placed on the soil and shaken occasionally for 24 hours. This process of challenging the same batch of soil with the number one extract of a waste was repeated until the soils had been exposed to a total of eight of these extracts. (The results of this work were not reported because the limiting capacity of the soil was not reached, and besides, the capacity thus determined would not apply for any other combination of extracts.) The soil remaining from these experiments was used to examine what could subsequently be extracted from them by water. First, this soil was extracted 24 hours using 2 milliliters of water per gram, then, after filtering, by 3 milliliters per gram, and afterward, by 6 and 12 milliliters water per gram of soil. The results of these water-flush experiments are given in Tables C-7 through C-9 for zinc-carbon battery waste and in Tables C-10 through C-12 for titanium dioxide pigment production waste.

Table C-1. Selected Metals Extracted by Water on Chalmers Soil Previously Exposed to Zinc-Carbon Battery Waste in Serial Batch Studies.

METAL	EXTRACT	LAYER [a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY(uMHOS)
LEAD	1	H20			.00	.00	.00				
		I	.00	.00	.07	.13	-.13	.00	.00	7.4	4600
	2	H20			.00	.00	.00				
		I	.00	.00	.09	.28	-.28	.00	.00	7.3	[illegible]
	3	H20			.00	.00	.00				
		I	.00	.00	.09	.54	-.54	.00	.00	7.3	11500
	4	H20			.00	.00	.00				
		I	.00	.00	.09	1.07	-1.07	.00	.00	6.9	15500
CADMIUM	1	H20			.00	.00	.00				
		I	.00	.00	.03	.06	-.36	.00	.00	7.4	4600
	2	H20			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	7.3	7400
	3	H20			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.3	11500
	4	H20			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	6.9	15500
ZINC	1	H20			.00	.00	.00				
		I	.00	.00	1.81	3.62	-3.62	.00	.00	7.4	4600
	2	H20			.00	.00	.00				
		I	.00	.00	.58	1.73	-1.73	.00	.00	7.3	7400
	3	H20			.00	.00	.00				
		I	.00	.00	.97	5.82	-5.82	.00	.00	7.3	11500
	4	H20			.00	.00	.00				
		I	.00	.00	.67	8.00	-8.00	.00	.00	6.9	15500

[a] I = batch of soil.

Table C-2. Selected Metals Extracted by Water on Davidson Soil Previously Exposed to Zinc-Carbon Battery Waste in Serial Batch Studies.

METAL	EXTRACT	LAYER [a]	CHALLENGE µg/mL	CHALLENGE µg/g	AMT. PENETRATING µg/mL	AMT. PENETRATING µg/g	WT RETAINED µg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (µMHOS)
LEAD	1	H2O			.00	.00	.00				
		I	.00	.00	.10	.19	-.19	.00	.00	6.8	5700
	2	H2O			.00	.00	.00				
		I	.00	.00	.09	.28	-.28	.00	.00	6.9	[illegible]
	3	H2O			.00	.00	.00				
		I	.00	.00	.10	.58	-.58	.00	.00	6.5	19000
	4	H2O			.00	.00	.00				
		I	.00	.00	.10	1.16	-1.16	.00	.00	7.2	12500
CADMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.01	.02	-.02	.00	.00	6.8	5700
	2	H2O			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	6.7	6200
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	6.5	19000
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	7.2	12500
ZINC	1	H2O			.00	.00	.00				
		I	.00	.00	.43	.87	-.87	.00	.00	6.8	5700
	2	H2O			.00	.00	.00				
		I	.00	.00	.17	.52	-.52	.00	.00	6.9	6200
	3	H2O			.00	.00	.00				
		I	.00	.00	.59	3.51	-3.51	.00	.00	6.5	19000
	4	H2O			.00	.00	.00				
		I	.00	.00	.11	1.33	-1.33	.00	.00	7.2	12500

[a] I = batch of soil.

Table C-3. Selected Metals Extracted by Water on Nicholson Soil Previously Exposed to Zinc-Carbon Battery Waste in Serial Batch Studies.

METAL	EXTRACT	LAYER [a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	AMT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (uMHOS)
LEAD	1	H20			.00	.00	.00				
		I	.00	.00	.07	.14	-.14	.00	.00	7.0	4900
	2	H20			.00	.00	.00				
		I	.00	.00	.07	.21	-.21	.00	.00	[illegible]	[illegible]
	3	H20			.00	.00	.00				
		I	.00	.00	.09	.52	-.52	.00	.00	7.0	8000
	4	H20			.00	.00	.00				
		I	.00	.00	.09	1.11	-1.11	.00	.00	7.0	9200
CADMIUM	1	H20			.00	.00	.00				
		I	.00	.00	.02	.04	-.04	.00	.00	7.0	4900
	2	H20			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	6.4	5600
	3	H20			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.0	8000
	4	H20			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	7.0	9200
ZINC	1	H20			.00	.00	.00				
		I	.00	.00	1.68	3.35	-3.35	.33	.50	7.0	4900
	2	H20			.00	.00	.00				
		I	.00	.00	1.26	3.79	-3.79	.00	.00	6.4	5600
	3	H20			.00	.00	.00				
		I	.00	.00	1.20	7.21	-7.21	.00	.00	7.0	8000
	4	H20			.00	.00	.00				
		I	.00	.00	.56	6.67	-6.67	.00	.00	7.0	9200

[a] I = batch of soil.

Table C-4. Selected Metals Extracted by Water on Chalmers Soil Previously Exposed to Titanium Dioxide Pigment Production Waste in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE vg/mL	CHALLENGE vg/g	AMT. PENETRATING vg/ml	AMT. PENETRATING vg/g	WT RETAINED vg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY(vMHOS)
CHROMIUM	1	H2O			.00	.00	.00				
		I	.03	.00	.03	.06	-.06	.00	.00	6.8	9000
		II	.03	.06	.02	.04	.02	.33	.33	7.5	5400
		III	.02	.04	.01	02	.02	.50	.50	7.3	7000
	2	H2O			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	7.0	5300
		II	.01	.03	.01	.03	.00	.00	.22	7.3	8000
		III	.01	.03	.02	.06	-.03	-1.00	-.14	7.4	7300
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.0	50000
		II	.01	.06	.01	.06	.00	.30	.13	7.1	11000
		III	.01	.06	.02	.12	-.06	-1.00	-.54	6.9	6400
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	6.5	27000
		II	.01	.12	.01	.12	.00	.00	.07	7.2	12000
		III	.01	.12	.01	.12	.00	.00	-.28	7.4	9600
TITANIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.10	.20	-.20	.00	.00	6.8	9000
		II	.10	.20	.10	.20	.00	.00	.00	7.5	5400
		III	.10	.20	.10	.20	.00	.00	.00	7.3	7000
	2	H2O			.00	.00	.00				
		I	.00	.00	.10	.30	-.30	.05	.00	7.0	5300
		II	.10	.30	.10	.30	.00	.00	.00	7.3	8000
		III	.10	.30	.10	.30	.00	.00	.00	7.4	7300
	3	H2O			.00	.00	.00				
		I	.00	.00	.10	.61	-.61	.00	.00	7.0	50000
		II	.10	.61	.10	.61	.00	.00	.00	7.1	11000
		III	.10	.61	.30	1.82	-1.21	-2.00	-1.00	6.9	6400
	4	H2O			.00	.00	.00				
		I	.00	.00	.10	1.21	-1.21	.00	.00	6.5	27000
		II	.10	1.21	.10	1.21	.00	.00	.00	7.2	12000
		III	.10	1.21	.10	1.21	.00	.00	-.52	7.4	9600

Table C-4. Selected Metals Extracted by Water on Chalmers Soil Previously Exposed to Titanium Dioxide Pigment Production Waste in Serial Batch Studies. (Cont.)

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/ml	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umHOS)
LEAD	1	H20			.00	.00	.00				
		I	.00	.00	.09	.17	-.17	.00	.00	6.8	9000
		II	.09	.17	.09	.16	.01	.08	.08	7.5	5400
		III	.08	.16	.08	.16	.00	.01	.01	7.3	7000
	2	H20			.00	.00	.00				
		I	.00	.00	.08	.25	-.25	.00	.00	7.0	5300
		II	.08	.25	.08	.25	.00	.01	.04	7.3	8000
		III	.08	.25	.08	.24	.01	.05	.03	7.4	7300
	3	H20			.00	.00	.00				
		I	.00	.00	.09	.55	-.55	.00	.00	7.0	50000
		II	.09	.55	.09	.52	.03	.05	.05	7.1	11000
		III	.09	.52	.09	.53	-.01	-.02	.01	6.9	6400
	4	H20			.00	.00	.00				
		I	.00	.00	.09	1.13	-1.13	.00	00	6.5	27000
		II	.09	1.13	.09	1.06	.07	.06	.06	7.2	12000
		III	.09	1.06	.09	1.03	.03	.03	.02	7.4	9600

[a]I,II,III designate three batches of soil that were extracted using leachate from the batch above it in the sequence.

Table C-5. Selected Metals Extracted by Water on Davidson Soil Previously Exposed to Titanium Dioxide Pigment Production Waste in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhOS)
CHROMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.05	.10	-.10	.00	.00	6.9	5100
		II	.05	.10	.01	.02	.08	.80	.80	7.3	4000
		III	.01	.02	.01	.02	.00	.00	.00	7.3	6200
	2	H2O			.00	.00	.00				
		I	.00	.00	.02	.06	-.06	.00	.00	6.4	12000
		II	.02	.06	.01	.03	.03	.50	.69	6.9	7400
		III	.01	.03	.01	.03	.00	.00	.00	7.0	6100
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.0	13000
		II	.01	.06	.01	.06	.00	.00	.50	7.0	9000
		III	.01	.06	.01	.06	.00	.00	.00	7.1	6000
	4	H2O			.00	.00	.00				
		I	.00	.00	.02	.24	-.24	.00	.00	6.6	23000
		II	.02	.24	.01	.12	.12	.50	.50	7.2	13500
		III	.01	.12	.01	.12	.00	.00	.00	7.4	8500
TITANIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.10	.36	-.36	.00	.00	6.9	5100
		II	.10	.36	.10	.20	.16	.44	.44	7.3	4000
		III	.10	.20	.10	.20	.00	.00	.00	7.3	6200
	2	H2O			.00	.00	.00				
		I	.00	.00	.10	.30	-.30	.30	.30	6.4	12000
		II	.10	.30	.10	.30	.00	.00	.25	6.9	7400
		III	.10	.30	.10	.30	.00	.00	.00	7.0	6100
	3	H2O			.00	.00	.00				
		I	.00	.00	.10	.61	-.61	.00	.00	7.0	13000
		II	.10	.61	.10	.61	.00	.00	.13	7.0	9000
		III	.10	.61	.10	.61	.00	.00	.00	7.1	6000
	4	H2O			.00	.00	.00				
		I	.00	.00	.10	1.21	-1.21	.00	.00	6.6	23000
		II	.10	1.21	.10	1.21	.00	.00	.07	7.2	13500
		III	.10	1.21	.10	1.21	.00	.00	.00	7.4	8500

Table C-5. Selected Metals Extracted by Water on Davidson Soil Previously Exposed to Titanium Dioxide Pigment Production Waste in Serial Batch Studies. (Cont.)

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (uMHOS)
LEAD	1	H20			.00	.00	.00				
		I	.00	.00	.08	.17	-.17	.00	.00	6.9	5100
		II	.08	.17	.08	.16	.01	.03	.03	7.3	4800
		III	.08	.16	.09	.17	-.01	-.05	-.05	7.3	6200
	2	H20			.00	.00	.00				
		I	.00	.00	.09	.27	-.27	.00	.00	6.4	12000
		II	.09	.27	.09	.26	.01	.05	.04	6.9	7400
		III	.09	.26	.08	.24	.02	.06	.02	7.0	6100
	3	H20			.00	.00	.00				
		I	.00	.00	.09	.55	-.55	.00	.00	7.0	13000
		II	.09	.55	.09	.53	.02	.04	.04	7.0	9000
		III	.09	.53	.08	.50	.03	.06	.04	7.1	6000
	4	H20			.00	.00	.00				
		I	.00	.00	.09	1.14	-1.14	.00	.00	6.6	23000
		II	.09	1.14	.09	1.10	.04	.04	.04	7.2	13500
		III	.09	1.10	.09	1.08	.01	.01	.03	7.4	8500

[a] I,II,III designate three batches of soil that were extracted using leachate from the batch above it in the sequence.

Table C-6. Selected Metals Extracted by Water on Nicholson Soil Previously Exposed to Titanium Dioxide Pigment Production Waste in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/mL	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (μMHOS)
CHROMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.01	.02	-.02	.00	.00	7.5	6200
		II	.01	.02	.02	.04	-.02	-1.00	-1.00	6.8	5400
		III	.02	.04	.01	.02	.02	.50	.50	6.4	6200
	2	H2O			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	6.7	9200
		II	.01	.03	.01	.03	.00	.00	-.40	7.0	7600
		III	.01	.03	.01	.03	.30	.90	.29	6.8	6800
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	6.8	12000
		II	.01	.06	.01	.06	.00	.00	-.10	6.8	11000
		III	.01	.06	.01	.06	.00	.00	.15	7.2	6000
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	7.0	13000
		II	.01	.12	.01	.12	.00	.00	-.09	7.2	12000
		III	.01	.12	.01	.12	.00	.00	.09	6.7	7600
TITANIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.10	.20	-.20	.00	.00	7.5	6200
		II	.10	.20	.24	.40	-.20	-1.00	-1.40	6.8	5400
		III	.24	.40	.10	.20	.20	.50	.50	6.4	6200
	2	H2O			.00	.00	.00				
		I	.00	.00	.10	.30	-.30	.00	.00	6.7	9200
		II	.10	.30	.10	.30	.00	.00	-.56	7.0	7600
		III	.10	.30	.10	.30	.00	.00	.36	6.8	6800
	3	H2O			.00	.00	.00				
		I	.00	.00	.10	.61	-.61	.00	.00	6.8	12000
		II	.10	.61	.16	.61	.00	.00	-.25	6.8	11000
		III	.10	.61	.17	1.03	-.42	-.70	-.10	7.2	6000
	4	H2O			.00	.00	.00				
		I	.00	.00	.12	1.45	-1.45	.00	.00	7.0	13000
		II	.12	1.45	.16	1.21	.24	.17	-.42	7.2	12000
		III	.10	1.21	.10	1.21	.00	.00	-.05	6.7	7600

Table C-6. Selected Metals Extracted by Water on Nicholson Soil Previously Exposed to Titanium Dioxide Pigment Production Waste in Serial Batch Studies. (Cont.)

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/mL	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY(uMHOS)
LEAD	1	H20			.00	.00	.00				
		I	.00	.00	.08	.17	-.17	.00	.00	7.5	6200
		II	.08	.17	.09	.17	-.00	-.01	-.01	6.8	5400
		III	.09	.17	.08	.17	.00	.02	.02	6.4	6200
	2	H20			.00	.00	.00				
		I	.00	.00	.09	.27	-.27	.00	.00	6.7	9200
		II	.09	.27	.09	.27	.01	.02	.01	7.0	7600
		III	.09	.27	.09	.26	.01	.03	.03	6.8	6800
	3	H20			.00	.00	.00				
		I	.00	.00	.09	.55	-.55	.00	.00	6.8	12000
		II	.09	.55	.09	.53	.01	.02	.02	6.8	11000
		III	.09	.53	.10	.58	-.05	-.08	-.03	7.2	6800
	4	H20			.00	.00	.00				
		I	.00	.00	.09	1.09	-1.09	.00	.00	7.0	13000
		II	.09	1.09	.09	1.09	.00	.00	.01	7.2	12000
		III	.09	1.09	.09	1.05	.04	.04	.00	6.7	7600

[a]I,II.III designate three batches of soil that were extracted using leachate from the batch above it in the sequence.

Table C-7. Selected Metals Extracted by Water on Chalmers Soil Previously Exposed to Zinc-Carbon Battery Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	AMT. RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umHOS)
LEAD	1	H2O			.00	.00	.00				
		I	.00	.00	.07	.14	-.14	.00	.00	7.1	51
	2	H2O			.00	.00	.00				
		I	.00	.00	.09	.26	-.26	.00	.00	7.2	170
	3	H2O			.00	.00	.00				
		I	.00	.00	.09	.57	-.57	.00	.00	7.6	1000
	4	H2O			.00	.00	.00				
		I	.00	.00	.10	1.15	-1.15	.00	.00	7.9	3800
CADMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.92	1.84	-1.84	.00	.00	7.1	51
	2	H2O			.00	.00	.00				
		I	.00	.00	.10	.30	-.30	.00	.00	7.2	170
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.6	1000
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	7.9	3800
ZINC	1	H2O			.00	.00	.00				
		I	.00	.00	23.63	47.27	-47.27	.00	.00	7.1	51
	2	H2O			.00	.00	.00				
		I	.00	.00	5.21	15.63	-15.63	.00	.00	7.2	170
	3	H2O			.00	.00	.00				
		I	.00	.00	.50	3.03	-3.03	.00	.00	7.6	1000
	4	H2O			.00	.00	.00				
		I	.00	.00	.25	3.03	-3.03	.00	.00	7.9	3800

[a] I = batch of soil.

Table C-8. Selected Metals Extracted by Water on Davidson Soil Previously Exposed to Zinc-Carbon Battery Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY(umhos)
LEAD	1	H2O			.00	.00	.00				
		I	.00	.00	.07	.14	-.14	.00	.00	6.9	42
	2	H2O			.00	.00	.00				
		I	.00	.00	.08	.25	-.25	.00	.00	7.0	115
	3	H2O			.00	.00	.00				
		I	.00	.00	.09	.56	-.56	.00	.00	7.0	520
	4	H2O			.00	.00	.00				
		I	.00	.00	.09	1.13	-1.13	.00	.00	6.6	2900
CADMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	1.64	3.27	-3.27	.03	.00	6.9	42
	2	H2O			.00	.00	.00				
		I	.00	.00	.55	1.64	-1.64	.00	.00	7.0	115
	3	H2O			.00	.00	.00				
		I	.00	.00	.07	.42	-.42	.00	.00	7.0	520
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	6.6	2900
ZINC	1	H2O			.00	.00	.00				
		I	.00	.00	28.58	57.17	-57.17	.00	.00	6.9	42
	2	H2O			.00	.00	.00				
		I	.00	.00	12.63	37.88	-37.88	.00	.00	7.0	115
	3	H2O			.00	.00	.00				
		I	.00	.00	2.80	16.79	-16.79	.00	.00	7.0	520
	4	H2O			.00	.00	.00				
		I	.00	.00	.50	6.06	-6.06	.00	.00	6.6	2900

[a] I = batch of soil.

Table C-9. Selected Metals Extracted by Water on Nicholson Soil Previously Exposed to Zinc-Carbon Battery Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE µg/mL	CHALLENGE µg/g	AMT. PENETRATING µg/mL	AMT. PENETRATING µg/g	AMT. RETAINED µg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (µMHOS)
LEAD	1	H2O			.00	.00	.00				
		I	.00	.00	.07	.13	-.13	.00	.00	6.9	64
	2	H2O			.00	.00	.00				
		I	.00	.00	.08	.25	-.25	.00	.00	7.1	180
		H2O			.00	.00	.00				
		I	.00	.00	.07	.56	-.56	.00	.00	7.3	300
	4	H2O			.00	.00	.00				
		I	.00	.00	.10	1.15	-1.15	.00	.00	7.4	2400
CADMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	1.21	2.42	-2.42	.00	.00	6.9	64
	2	H2O			.00	.00	.00				
		I	.00	.00	.15	.45	-.45	.00	.00	7.1	180
	3	H2O			.00	.00	.00				
		I	.00	.00	.04	.24	-.24	.00	.00	7.3	300
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	7.4	2400
ZINC	1	H2O			.00	.00	.00				
		I	.00	.00	16.87	33.73	-33.73	.00	.00	6.9	64
	2	H2O			.00	.00	.00				
		I	.00	.00	3.97	11.91	-11.91	.00	.00	7.1	180
	3	H2O			.00	.00	.00				
		I	.00	.00	1.65	9.88	-9.88	.00	.00	7.3	300
	4	H2O			.00	.00	.00				
		I	.00	.00	.16	1.94	-1.94	.00	.00	7.4	2400

[a] I = batch of soil.

Table C-10. Selected Metals Extracted by Water on Chalmers Soil Previously Exposed to Titanium Dioxide Pigment Production Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umHOS)
CHROMIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.04	.08	-.08	.00	.00	7.3	1100
	2	H2O			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	7.1	3000
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.1	4800
	4	H2O			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	6.2	13500
TITANIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.13	.26	-.26	.00	.00	7.3	1100
	2	H2O			.00	.00	.00				
		I	.00	.00	.16	.38	-.38	.00	.00	7.1	3000
	3	H2O			.00	.00	.00				
		I	.00	.00	.10	.61	-.61	.00	.00	7.1	4800
	4	H2O			.00	.00	.00				
		I	.00	.00	.12	1.45	-1.45	.00	.00	6.2	13500
LEAD	1	H2O			.00	.00	.00				
		I	.00	.00	.08	.16	-.16	.00	.00	7.3	1100
	2	H2O			.00	.00	.00				
		I	.00	.00	.02	.07	-.07	.00	.00	7.1	3000
	3	H2O			.00	.00	.00				
		I	.00	.00	.08	.46	-.46	.00	.00	7.1	4800
	4	H2O			.00	.00	.00				
		I	.00	.00	.09	1.18	-1.18	.00	.00	6.2	13500

[a] I = batch of soil.

Table C-11. Selected Metals Extracted by Water on Davidson Soil Previously Exposed to Titanium Dioxide Pigment Production Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (uMHOS)
CHROMIUM	1	H20			.10	.00	.30				
		I	.00	.00	.04	.08	-.08	.00	.00	7.2	740
	2	H20			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	7.6	1300
	3	H20			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.5	4900
	4	H20			.00	.00	.00				
		I	.00	.00	.01	.12	-.12	.00	.00	6.4	14000
TITANIUM	1	H20			.00	.00	.00				
		I	.00	.00	.23	.46	-.46	.00	.00	7.2	740
	2	H20			.00	.00	.00				
		I	.00	.00	.10	.30	-.30	.00	.00	7.6	1300
	3	H20			.00	.00	.00				
		I	.00	.00	.10	.61	-.61	.00	.00	7.5	4900
	4	H20			.00	.00	.00				
		I	.00	.00	.10	1.21	-1.21	.00	.00	6.4	14000
LEAD	1	H20			.00	.00	.00				
		I	.00	.00	.06	.11	-.11	.00	.00	7.2	740
	2	H20			.00	.00	.00				
		I	.00	.00	.02	.05	-.05	.00	.00	7.6	1300
	3	H20			.00	.00	.00				
		I	.00	.00	.08	.48	-.48	.00	.00	7.5	4900
	4	H20			.00	.00	.00				
		I	.00	.00	.09	1.08	-1.08	.00	.00	6.4	14000

[a]I = batch of soil.

Table C-12. Selected Metals Extracted by Water on Nicholson Soil Previously Exposed to Titanium Dioxide Pigment Production Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER [a]	CHALLENGE mg/mL	CHALLENGE ug/g	AMT. PENETRATING mg/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umHOS)
CHROMIUM	1	H2O			.00	.00	.03				
		I	.00	.00	.04	.08	-.08	.00	.00	7.3	830
	2	H2O			.00	.00	.00				
		I	.00	.00	.01	.03	-.03	.00	.00	7.1	1300
	3	H2O			.00	.00	.00				
		I	.00	.00	.01	.06	-.06	.00	.00	7.1	4100
	4	H2O			.00	.00	.00				
		I	.00	.00	.31	.12	-.12	.00	.00	6.4	11000
TITANIUM	1	H2O			.00	.00	.00				
		I	.00	.00	.27	.55	-.55	.00	.00	7.3	830
	2	H2O			.00	.00	.00				
		I	.00	.00	.12	.36	-.36	.00	.00	7.1	1300
	3	H2O			.00	.00	.00				
		I	.00	.00	.10	.61	-.61	.00	.00	7.1	4100
	4	H2O			.00	.00	.00				
		I	.00	.00	.10	1.21	-1.21	.00	.00	6.4	11000
LEAD	1	H2O			.00	.00	.00				
		I	.00	.00	.10	.19	-.19	.00	.00	7.3	830
	2	H2O			.00	.00	.00				
		I	.00	.00	.02	.06	-.06	.00	.00	7.1	1300
	3	H2O			.00	.00	.00				
		I	.00	.00	.08	.47	-.47	.00	.00	7.1	4100
	4	H2O			.00	.00	.00				
		I	.00	.00	.09	1.08	-1.08	.00	.00	6.4	11000

[a] I = batch of soil.

APPENDIX D

RESULTS OF PUTTING FRESH WASTE ON WASTES AND/OR SOILS PREVIOUSLY EXPOSED TO WASTE LEACHATE

WASTE AND SOILS LEFT FROM SERIAL BATCH EXTRACTION EXPERIMENTS

To simulate the effect of dumping a new batch of waste upon an old deposit of the same waste, batches of waste and soil that had been previously subjected to a series of seven serial batch extractions by water were challenged by the water-extracts from a new batch of waste. The new batch of waste was first extracted with 2 milliliters of water per gram. After 24 hours with several shakings, the waste was filtered and the filtrate was placed on the waste left from the experiments described in the body of this report. This first extract was used to challenge Batch I of the three soils, the resulting filtrate was put on Batch II, and this extract was placed on Batch III using the procedure described in Section 4, page 10. Meanwhile, the new waste was extracted with 3, 6, and 12 milliliters per gram, which was used in the same way to challenge the old wastes and soils. The results of analyzing aliquots of the extracts at each stage of this experiment are shown in Tables D-1 through D-3 and Figures D-1 through D-9 for zinc-carbon battery waste and in Tables D-4 through D-6 and Figures D-10 through D-19 for titanium dioxide pigment production waste.

SOILS LEFT FROM SOIL CAPACITY EXPERIMENTS

A portion of each of the soils saved from the soil capacity experiments described in Appendix C were challenged by extracts of fresh waste. These experiments were run as described above except that the new waste leachate was put directly on the soil, not on old waste first. The results are presented in Tables D-7 through D-9 for zinc-carbon battery waste and in Tables D-10 through D-12 for titanium dioxide pigment production waste.

Table D-1. Selected Metals Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/mL	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (uMHOS)
LEAD	1	NW	.00	.00	.05	.10	-.10			7.4	70
		OW	.05	.10	.10	.21	-.10	-1.00	-1.00	7.4	18
		I	.10	.21	-.01	-.02	.23	1.09	1.09	7.0	40
	2	NW	.00	.00	.09	.26	-.26			7.6	66
		OW	.09	.26	.08	.25	.01	.04	-.26	7.6	54
		I	.08	.25	.02	.07	.17	.70	.88	7.0	46
	3	NW	.00	.00	.10	.57	-.57			7.9	500
		OW	.10	.57	.09	.55	.02	.03	-.08	7.6	230
		I	.09	.55	.08	.48	.08	.14	.47	7.2	120
	4	NW	.00	.00	.09	1.14	-1.14			7.6	680
		OW	.09	1.14	.10	1.15	-.01	-.01	-.04	7.6	560
		I	.10	1.15	.09	1.10	.05	.04	.24	7.3	360
CADMIUM	1	NW	.00	.00	4.14	8.28	-8.28			7.4	70
		OW	4.14	8.28	5.86	11.72	-3.43	-.41	-.41	7.4	18
		I	5.86	11.72	2.45	4.91	6.81	.58	.58	7.0	40
	2	NW	.00	.00	1.14	3.42	-3.42			7.6	66
		OW	1.14	3.42	1.60	4.79	-1.36	-.40	-.41	7.6	54
		I	1.60	4.79	1.64	4.91	-.12	-.03	.41	7.0	46
	3	NW	.00	.00	.12	.73	-.73			7.9	500
		OW	.12	.73	.43	2.61	-1.88	-2.58	-.54	7.6	230
		I	.43	2.61	.43	2.61	.00	.00	.35	7.2	120
	4	NW	.00	.00	.08	.97	-.97			7.6	680
		OW	.08	.97	.11	1.33	-.36	-.30	-.53	7.6	560
		I	.11	1.33	.06	.73	.61	.45	.36	7.3	360
ZINC	1	NW	.00	.00	387.84	775.68	-775.68			7.4	70
		OW	387.84	775.68	399.96	799.92	-24.24	-.03	-.03	7.4	18
		I	399.96	799.92	87.47	174.93	624.99	.78	.78	7.0	40
	2	NW	.00	.00	54.74	164.23	-164.23			7.6	66
		OW	54.74	164.23	70.19	210.58	-46.36	-.28	-.08	7.6	54
		I	70.19	210.58	35.96	107.87	102.72	.49	.72	7.0	46
	3	NW	.00	.00	6.87	41.21	-41.21			7.9	500
		OW	6.87	41.21	17.27	103.63	-62.42	-1.51	-.14	7.6	230
		I	17.27	103.63	12.02	72.11	31.51	.30	.68	7.2	120
	4	NW	.00	.00	3.10	37.21	-37.21			7.6	680
		OW	3.10	37.21	4.22	50.66	-13.45	-.36	-.14	7.6	560
		I	4.22	50.66	2.10	25.21	25.45	.50	.67	7.3	360

[a]NW = new waste; OW = old waste; I = batch of soil.

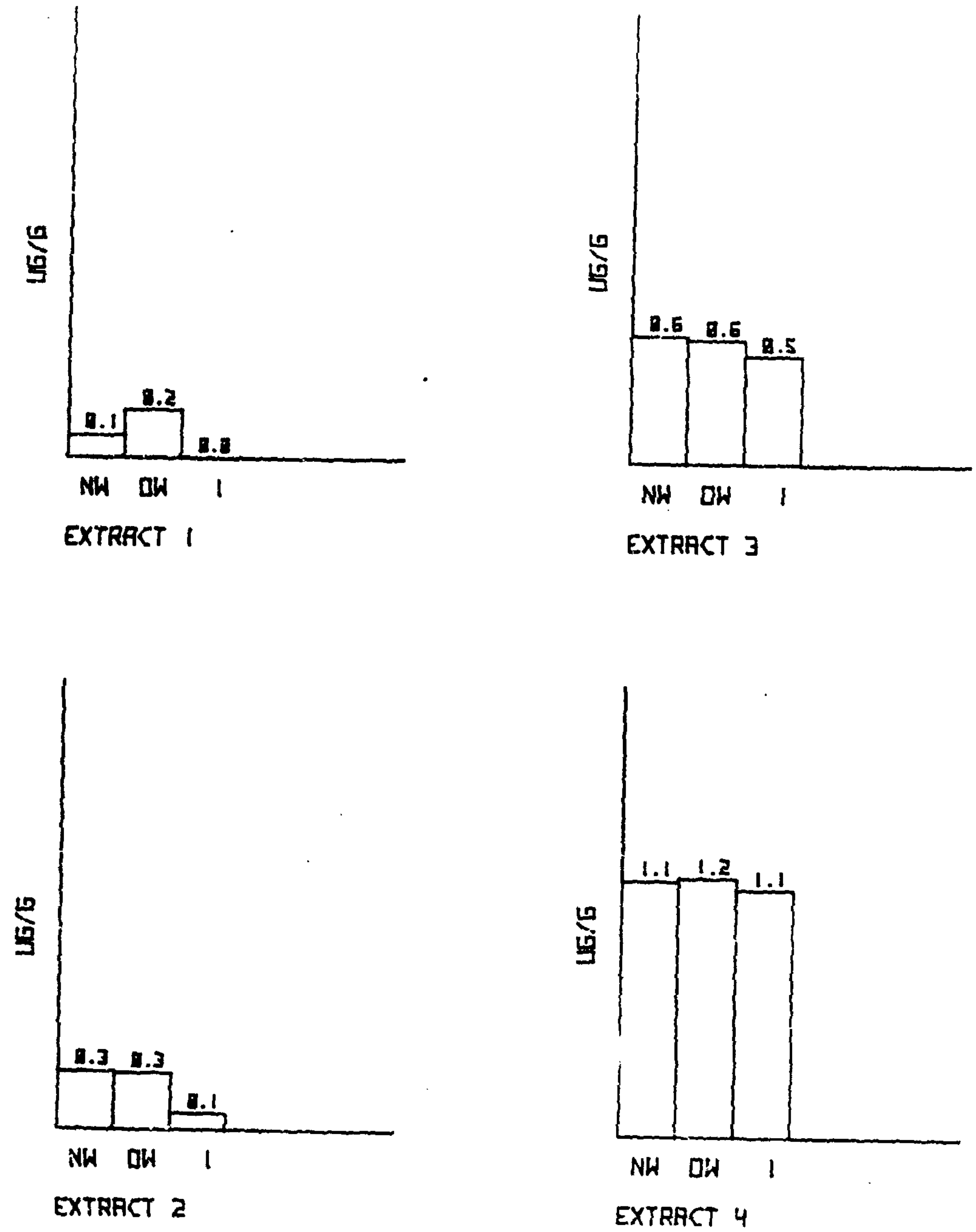

Figure D-1. Lead Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

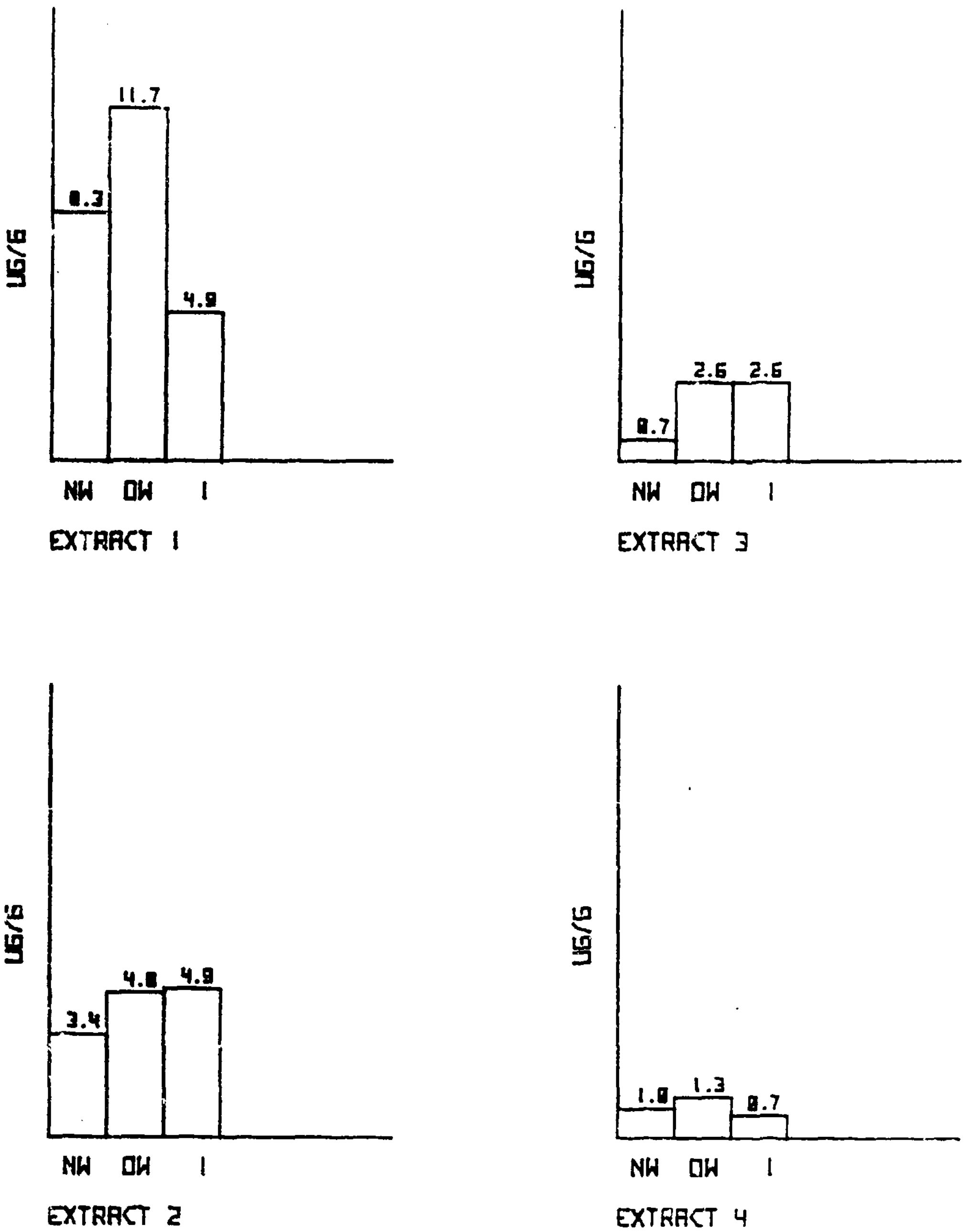

Figure D-2. Cadmium Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

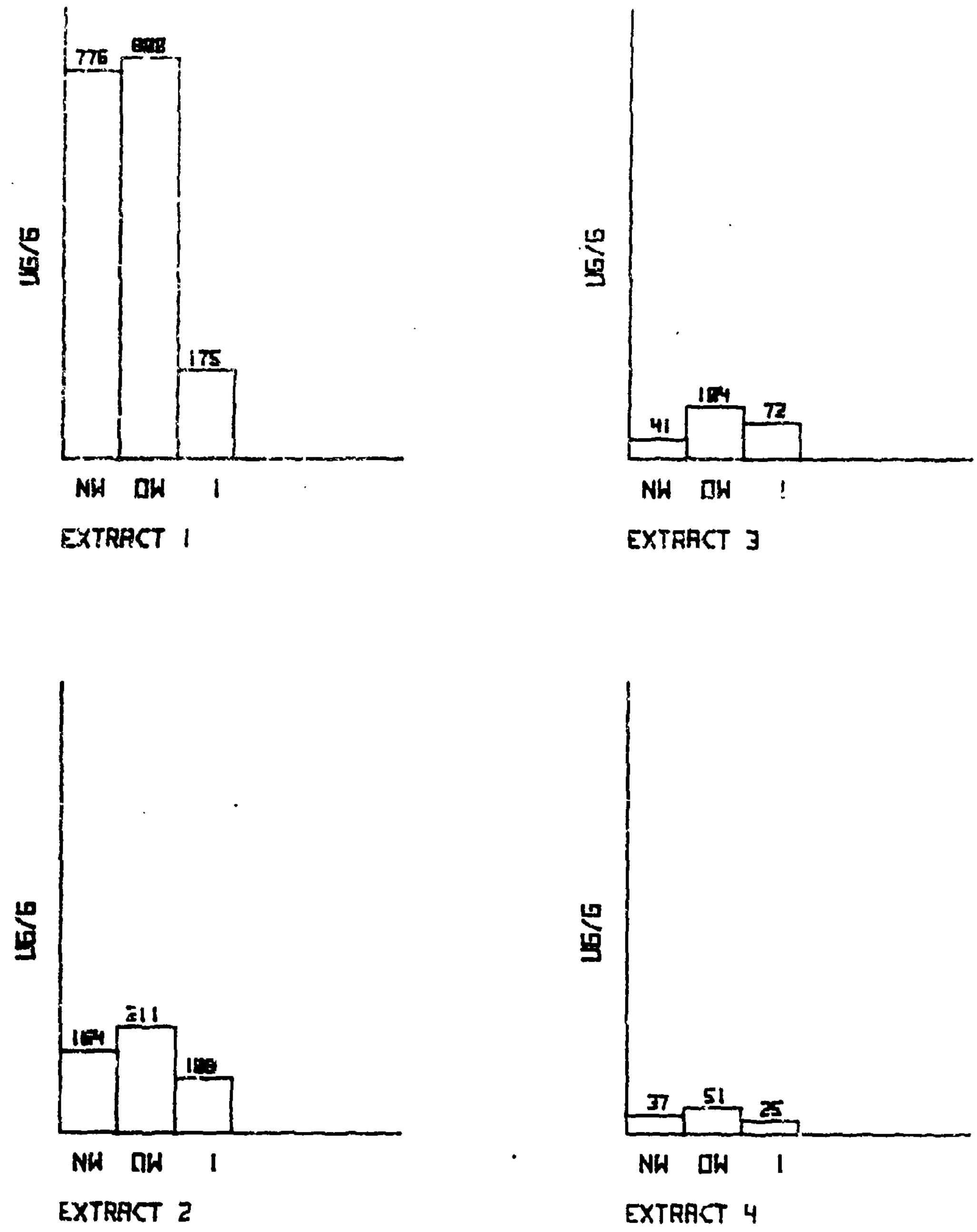

Figure D-3. Zinc Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

Table D-2. Selected Metals Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE µg/mL	CHALLENGE µg/g	AMT. PENETRATING µg/mL	AMT. PENETRATING µg/g	AMT RETAINED µg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (µMHOS)
LEAD	1	NW	.00	.00	.05	.10	-.10			7.4	70
		OW	.05	.10	.10	.21	-.10	-1.00	-1.00	7.4	18
		I	.10	.21	.03	.06	.15	.71	.71	6.6	30
	2	NW	.00	.00	.09	.26	-.26			7.6	66
		OW	.09	.26	.08	.25	.01	.04	-.26	7.6	54
		I	.08	.25	.06	.19	.05	.22	.45	6.8	4
	3	NW	.00	.00	.10	.57	-.57			7.9	500
		OW	.10	.57	.09	.55	.02	.03	-.08	7.6	230
		I	.09	.55	.08	.50	.05	.09	.25	6.8	120
	4	NW	.00	.00	.09	1.14	-1.14			7.6	680
		OW	.09	1.14	.10	1.15	-.01	-.01	-.04	7.5	560
		I	.10	1.15	.09	1.13	.02	.02	.13	7.1	420
CADMIUM	1	NW	.00	.00	4.14	8.28	-8.28			7.4	70
		OW	4.14	8.28	5.86	11.72	-3.43	-.41	-.41	7.4	18
		I	5.86	11.72	2.91	5.82	5.90	.50	.50	6.6	30
	2	NW	.00	.00	1.14	3.42	-3.42			7.6	66
		OW	1.14	3.42	1.60	4.79	-1.36	-.40	-.41	7.6	54
		I	1.60	4.79	1.45	4.36	.42	.09	.38	6.8	40
	3	NW	.00	.00	.12	.73	-.73			7.9	500
		OW	.12	.73	.43	2.61	-1.88	-2.58	-.54	7.6	230
		I	.43	2.61	.45	2.73	-.12	-.05	.32	6.8	120
	4	NW	.00	.00	.08	.97	-.97			7.6	680
		OW	.08	.97	.11	1.33	-.36	-.38	-.53	7.6	560
		I	.11	1.33	.03	.36	.97	.73	.35	7.1	420
ZINC	1	NW	.00	.00	387.84	775.68	-775.68			7.4	70
		OW	387.84	775.68	399.96	799.92	-24.24	-.03	-.03	7.4	18
		I	399.96	799.92	70.19	140.39	659.53	.82	.82	6.6	30
	2	NW	.00	.00	54.74	164.23	-164.23			7.6	66
		OW	54.74	164.23	70.19	210.58	-46.36	-.28	-.08	7.6	54
		I	70.19	210.58	29.79	89.38	121.20	.58	.77	6.8	40
	3	NW	.00	.00	6.87	41.21	-41.21			7.9	500
		OW	6.87	41.21	17.27	103.63	-62.42	-1.51	-.14	7.6	230
		I	17.27	103.63	11.41	68.48	35.15	.34	.73	6.8	120
	4	NW	.00	.00	3.10	37.21	-37.21			7.6	680
		OW	3.10	37.21	4.22	50.66	-13.45	-.36	-.14	7.6	560
		I	4.22	50.66	1.44	17.33	33.33	.66	.73	7.1	420

[a]NW = new waste; OW = [illegible]d waste; I = batch of soil.

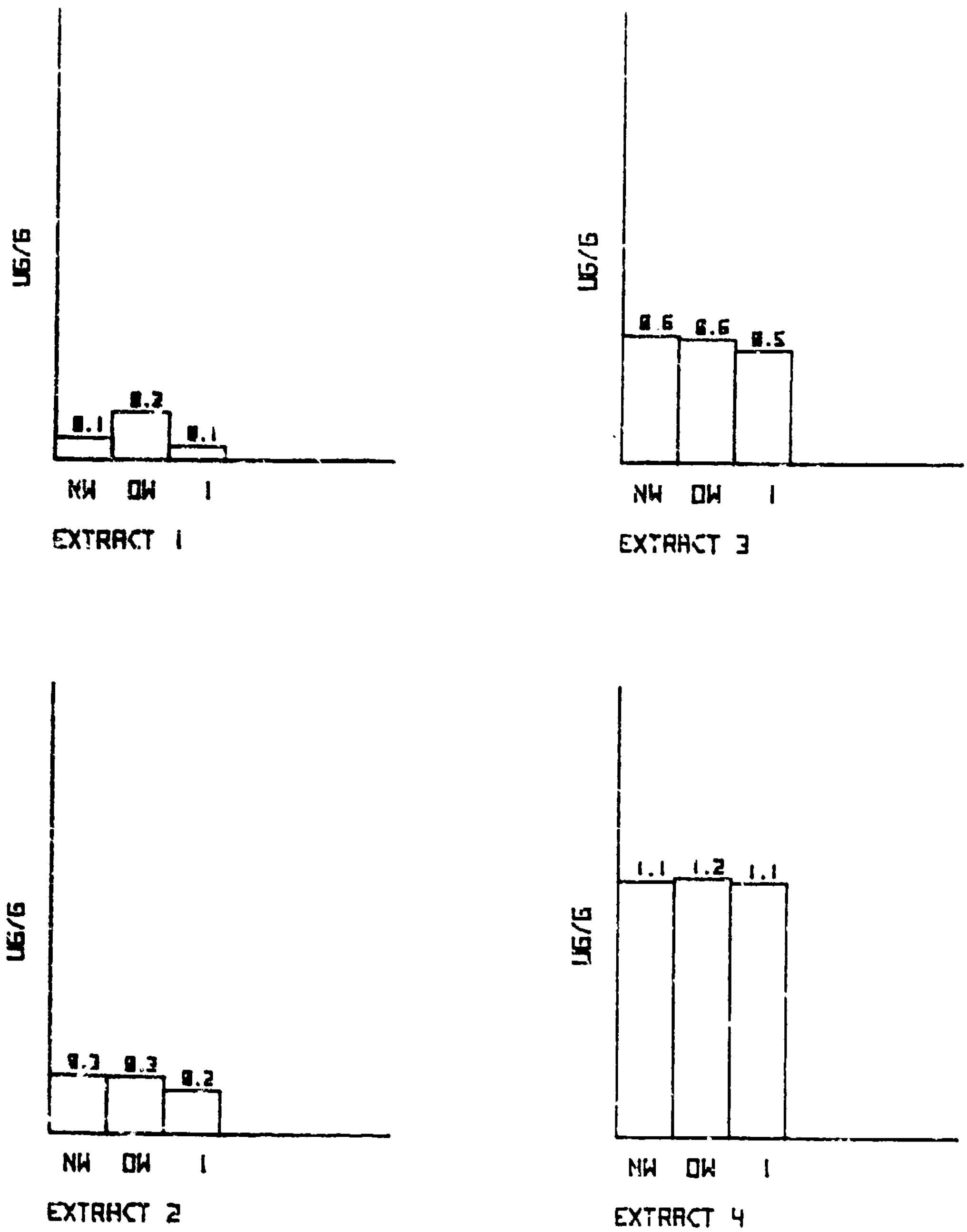

Figure D-4. Lead Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

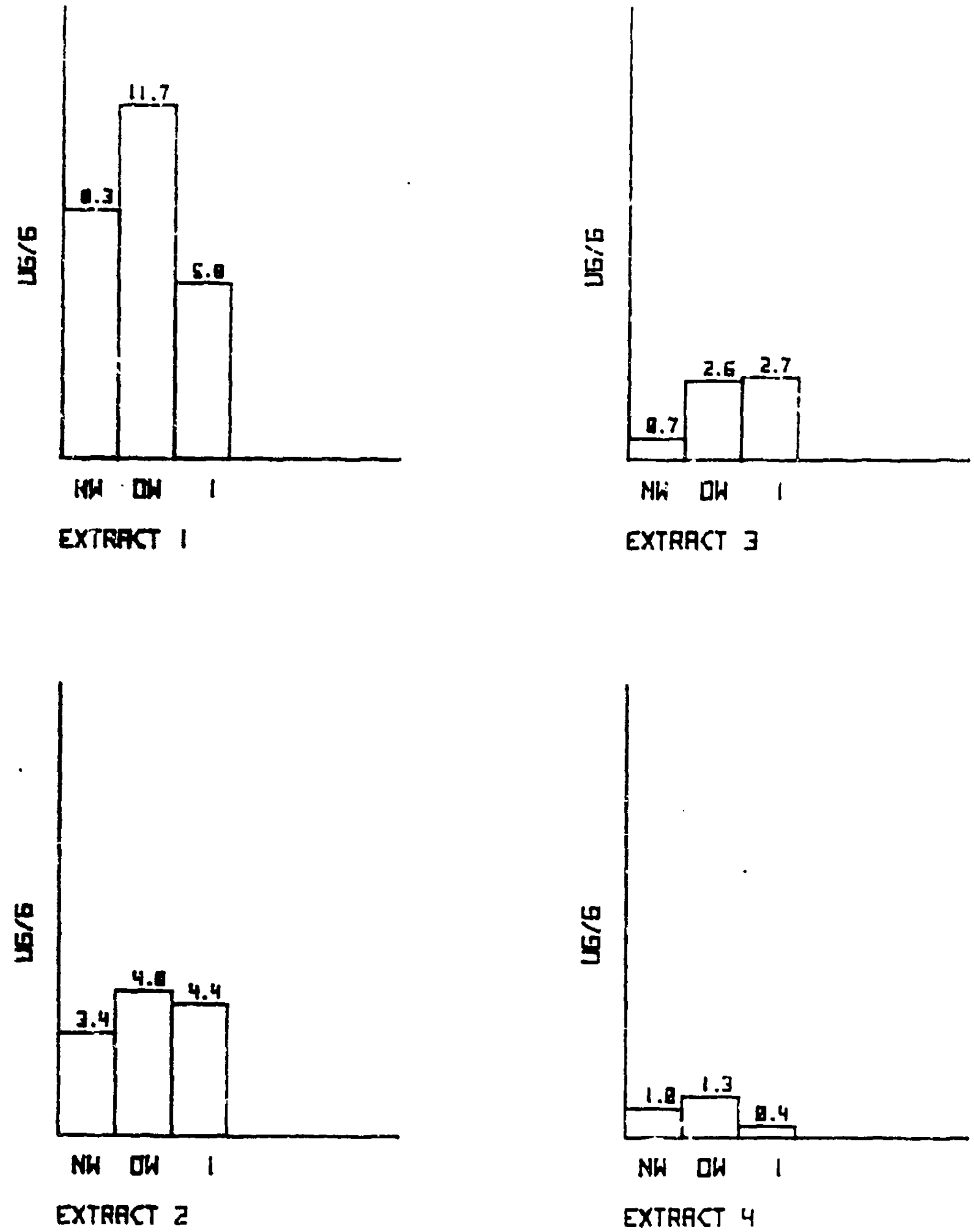

Figure D-5. Cadmium Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

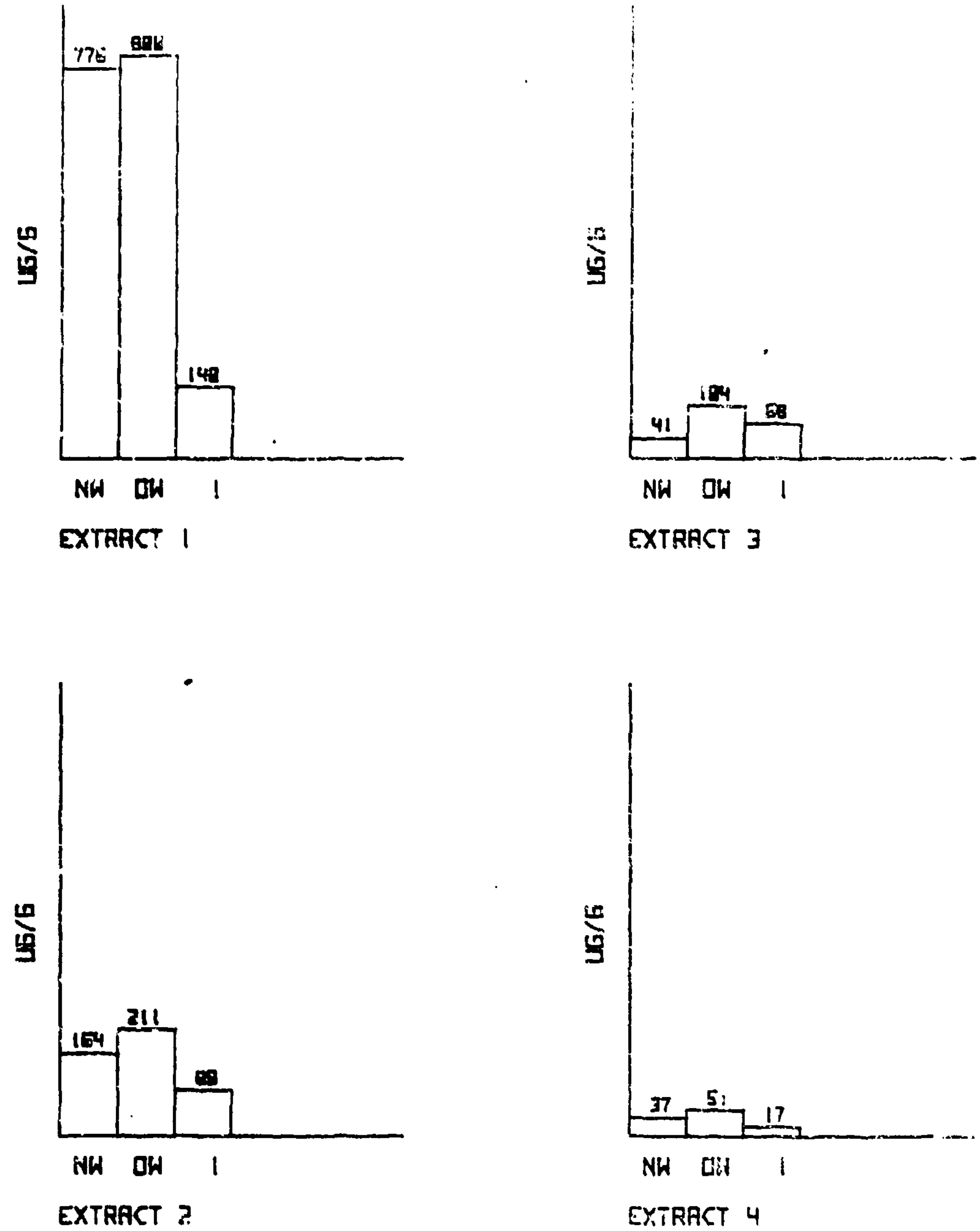

Figure D-6. Zinc Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

Table D-3. Selected Metals Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	ART. PENETRATING ug/mL	ART. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhos)
LEAD	1	NW	.00	.00	.05	.10	-.10			7.4	70
		OW	.05	.10	.10	.21	-.11	-1.00	-1.10	7.4	18
		I	.10	.21	.01	.02	.18	.89	.89	6.7	45
	2	NW	.00	.00	.09	.26	-.26			7.6	66
		OW	.09	.26	.08	.25	.01	.04	-.26	7.6	54
		I	.08	.25	.03	.10	.15	.61	.74	6.8	45
	3	NW	.00	.00	.10	.57	-.57			7.9	500
		OW	.10	.57	.09	.55	.02	.03	-.08	7.6	230
		I	.09	.55	.06	.47	.08	.15	.41	7.0	110
	4	NW	.00	.00	.09	1.14	-1.14			7.6	680
		OW	.09	1.14	.10	1.15	-.01	-.01	-.04	7.6	560
		I	.10	1.15	.09	1.11	.03	.03	.21	7.2	330
MANGANESE	1	NW	.00	.00	4.14	8.28	-8.28			7.4	70
		OW	4.14	8.28	5.86	11.72	-3.43	-.41	-.41	7.4	18
		I	5.86	11.72	2.01	4.02	7.70	.66	.66	6.7	45
	2	NW	.00	.00	1.14	3.42	-3.42			7.6	66
		OW	1.14	3.42	1.60	4.79	-1.35	-.40	-.41	7.6	54
		I	1.60	4.79	1.57	4.70	.09	.02	.47	6.8	45
	3	NW	.00	.00	.12	.73	-.73			7.9	500
		OW	.12	.73	.43	2.61	-1.88	-2.58	-.54	7.6	230
		I	.43	2.61	.47	2.85	-.24	-.09	.39	7.0	110
	4	NW	.00	.00	.08	.97	-.97			7.6	680
		OW	.08	.97	.11	1.33	-.36	-.38	-.53	7.6	560
		I	.11	1.33	.06	.73	.61	.45	.42	7.2	330
ZINC	1	NW	.00	.00	387.84	775.68	-775.68			7.4	70
		OW	387.84	775.68	399.96	799.92	-24.24	-.03	-.03	7.4	18
		I	399.96	799.92	61.41	122.82	677.10	.85	.85	6.7	45
	2	NW	.00	.00	54.74	164.23	-164.23			7.6	66
		OW	54.74	164.23	73.19	219.58	-46.36	-.28	-.08	7.6	54
		I	73.19	219.58	32.93	98.78	111.81	.53	.78	6.8	45
	3	NW	.00	.00	6.87	41.21	-41.21			7.9	500
		OW	6.87	41.21	17.27	103.63	-62.42	-1.51	-.14	7.6	230
		I	17.27	103.63	9.57	57.45	46.18	.45	.75	7.0	110
	4	NW	.00	.00	3.10	37.21	-37.21			7.6	680
		OW	3.10	37.21	4.22	50.66	-13.45	-.36	-.14	7.6	560
		I	4.22	50.66	1.72	20.60	30.06	.59	.74	7.2	330

[a]NW = new waste; OW = old waste; I = batch of soil.

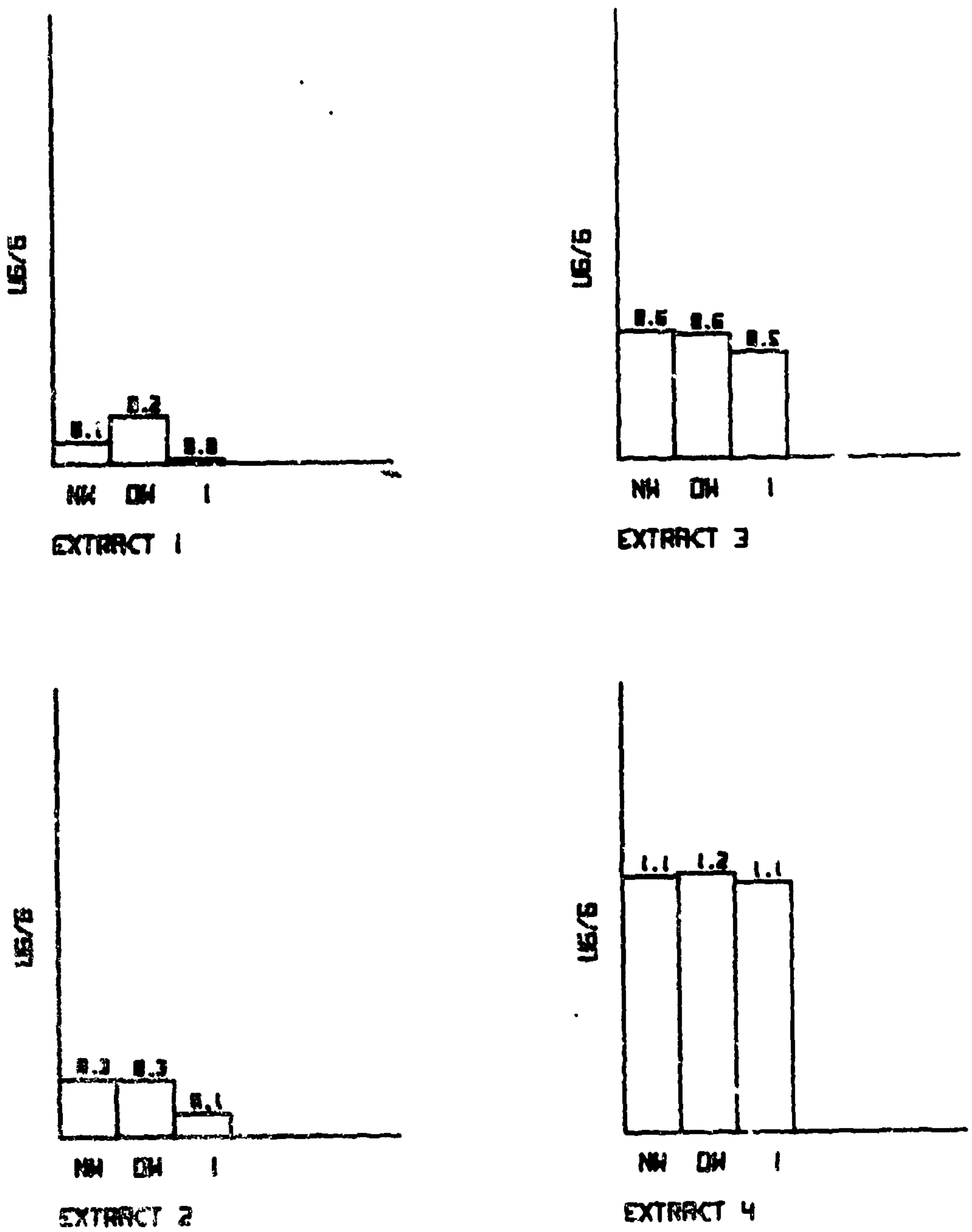

Figure D-7. Lead Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

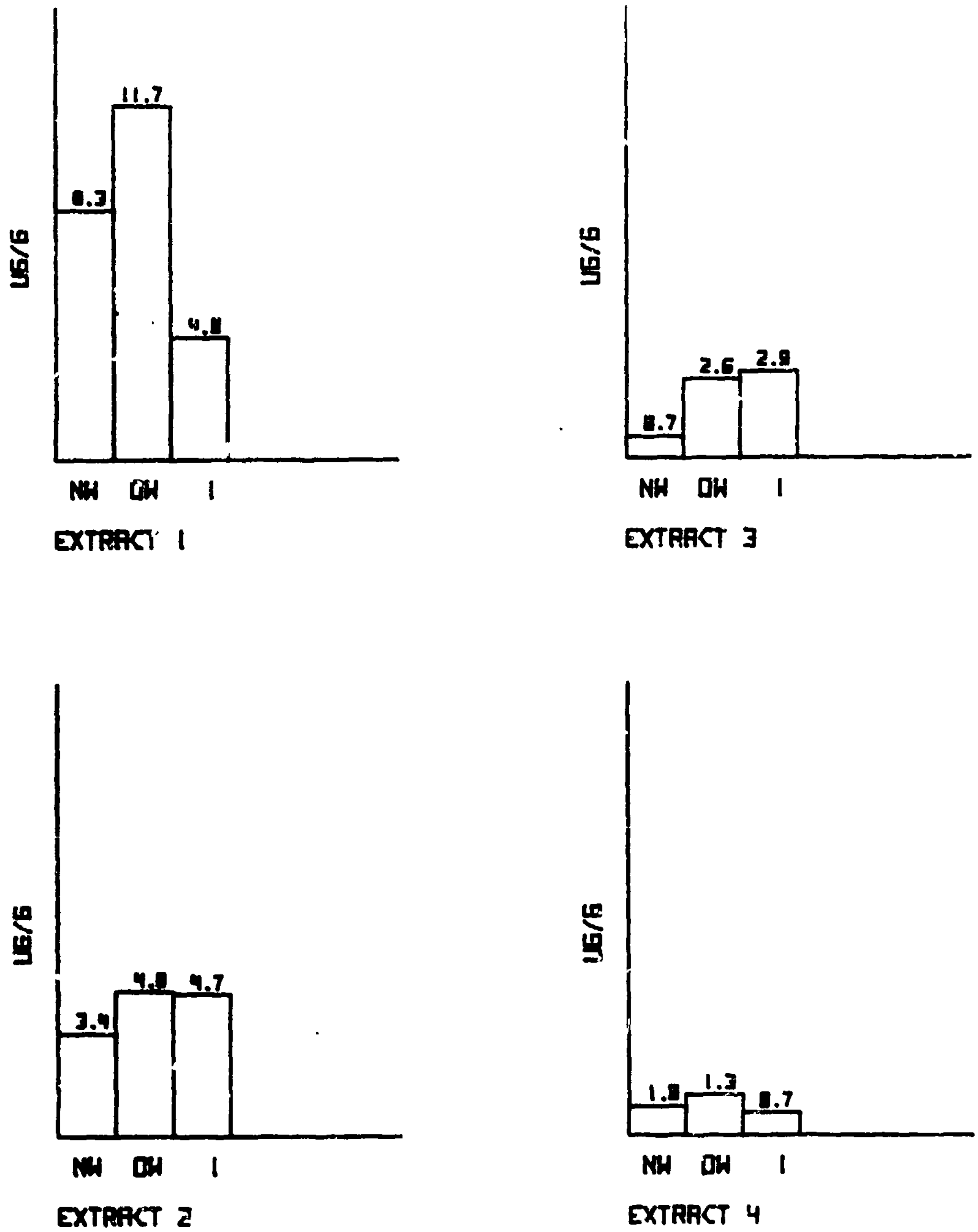

Figure D-8. Cadmium Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

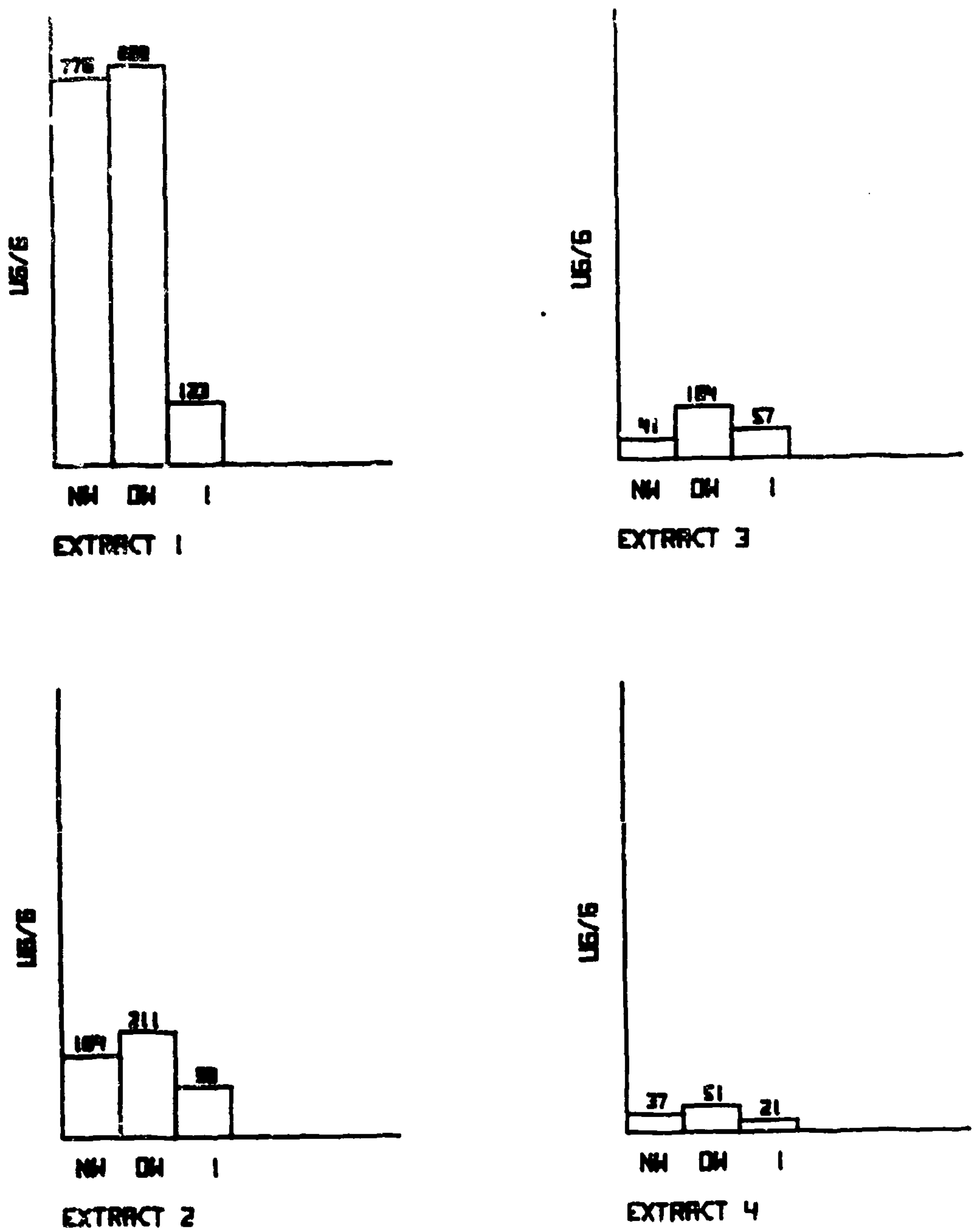

Figure D-9. Zinc Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Zinc-Carbon Battery Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

Table D-4. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE µg/mL	CHALLENGE µg/g	AMT. PENETRATING µg/mL	AMT. PENETRATING µg/g	WT RETAINED µg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (µMHOS)
CHROMIUM	1	NW	.00	.00	.07	.14	-.14			7.5	290
		OW	.07	.14	.06	.12	.02	.14	.14	7.6	560
		I	.06	.12	.03	.06	.06	.50	.50	7.3	600
		II	.03	.06	.02	.04	.02	.33	.33	7.3	960
		III	.02	.04	.02	.04	.00	.00	.00	7.0	1500
	2	NW	.00	.00	.06	.18	-.18			7.4	330
		OW	.06	.18	.05	.15	.03	.17	.16	7.8	479
		I	.05	.15	.04	.12	.03	.20	.33	7.4	430
		II	.04	.12	.02	.06	.06	.50	.44	7.2	615
		III	.02	.06	.05	.15	-.09	-1.50	-.90	7.1	760
	3	NW	.00	.00	.03	.18	-.18			6.9	600
		OW	.03	.18	.05	.30	-.12	-.67	-.14	7.5	630
		I	.05	.30	.03	.18	.12	.40	.37	7.6	605
		II	.03	.18	.04	.24	-.06	-.33	.06	7.5	580
		III	.04	.24	.02	.12	.12	.50	.09	7.5	610
	4	NW	.00	.00	.01	.12	-.12			7.6	1500
		OW	.01	.12	.03	.36	-.24	-2.00	-.50	7.5	1100
		I	.03	.36	.02	.24	.12	.33	.35	7.7	1100
		II	.02	.24	.02	.24	.00	.00	.03	7.4	910
		III	.02	.24	.02	.24	.00	.00	.05	7.4	740
TITANIUM	1	NW	.00	.00	.58	1.15	-1.15			7.6	200
		OW	.58	1.15	.22	.44	.71	.61	.61	7.6	560
		I	.22	.44	.10	.20	.24	.55	.55	7.3	600
		II	.10	.20	.15	.30	-.10	-.50	-.50	7.3	960
		III	.15	.30	.11	.22	.08	.27	.27	7.0	1500
	2	NW	.00	.00	.42	1.27	-1.27			7.4	330
		OW	.42	1.27	.21	.64	.64	.50	.55	7.8	470
		I	.21	.64	.17	.52	.12	.19	.34	7.4	430
		II	.17	.52	.10	.30	.21	.41	.15	7.2	615
		III	.10	.30	.19	.58	-.27	-.90	-.32	7.1	760
	3	NW	.00	.00	.19	1.15	-1.15			6.9	600
		OW	.19	1.15	.20	1.21	-.06	-.05	.36	7.5	630
		I	.20	1.21	.19	1.15	.06	.05	.19	7.6	605
		II	.19	1.15	.12	.73	.42	.37	.29	7.5	580
		III	.12	.73	.12	.73	.00	.00	-.14	7.5	610
	4	NW	.00	.00	.10	1.21	-1.21			7.6	1500
		OW	.10	1.21	.10	1.21	.00	.00	.27	7.5	1100
		I	.10	1.21	.10	1.21	.00	.00	.12	7.7	1100
		II	.10	1.21	.11	1.33	-.12	-.10	.13	7.4	910
		III	.11	1.32	.10	1.21	.12	.09	-.03	7.4	740

Table D-4. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies. (Cont.)

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (uMHOS)
LEAD	1	NW	.00	.00	.23	.46	-.46			7.5	200
		OW	.23	.46	.07	.14	.33	.71	.71	7.6	560
		I	.07	.14	.02	.04	.09	.68	.68	7.3	600
		II	.02	.04	.02	.04	.00	.06	.06	7.3	960
		III	.02	.04	.02	.04	-.00	-.01	-.01	7.0	1500
	2	NW	.00	.06	.11	.32	-.32			7.4	330
		OW	.11	.32	.06	.17	.15	.47	.61	7.8	470
		I	.06	.17	-.02	-.05	.22	1.30	1.03	7.4	430
		II	-.02	-.05	.07	.21	-.26	5.00	32.97	7.2	615
		III	.07	.21	.11	.33	-.13	-.62	-.52	7.1	760
	3	NW	.00	.00	.03	.20	-.20			6.9	600
		OW	.03	.20	.06	.30	-.17	-.05	.31	7.5	630
		I	.06	.30	.01	.03	.34	.92	.96	7.6	605
		II	.01	.03	-.02	-.12	.15	4.77	-4.31	7.5	580
		III	-.02	-.12	-.02	-.12	.00	.00	-1.01	7.5	610
	4	NW	.00	.00	.02	.27	-.27			7.6	1500
		OW	.02	.27	.03	.42	-.14	-.52	.13	7.5	1109
		I	.03	.42	-.03	-.36	.77	1.05	1.30	7.7	1100
		II	-.03	-.36	-.02	-.22	-.13	.30	.72	7.4	910
		III	-.02	-.22	.05	.63	-.05	3.06	10.42	7.4	740

[a]NW = new waste; OW = old waste; I,II,III designate three batches of soil, each of which were extracted using leachate from the batch above it in the sequence.

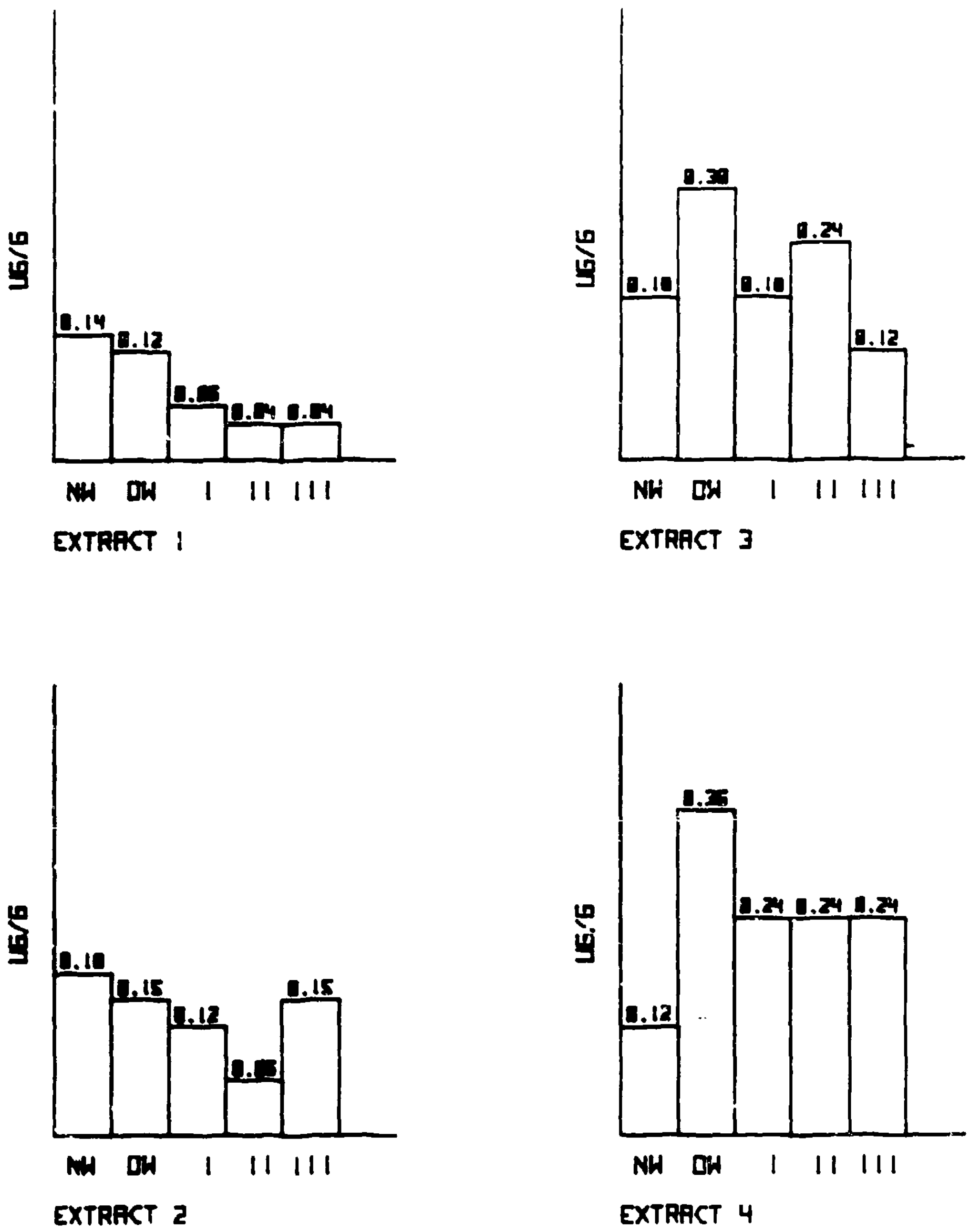

Figure D-10. Chromium Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

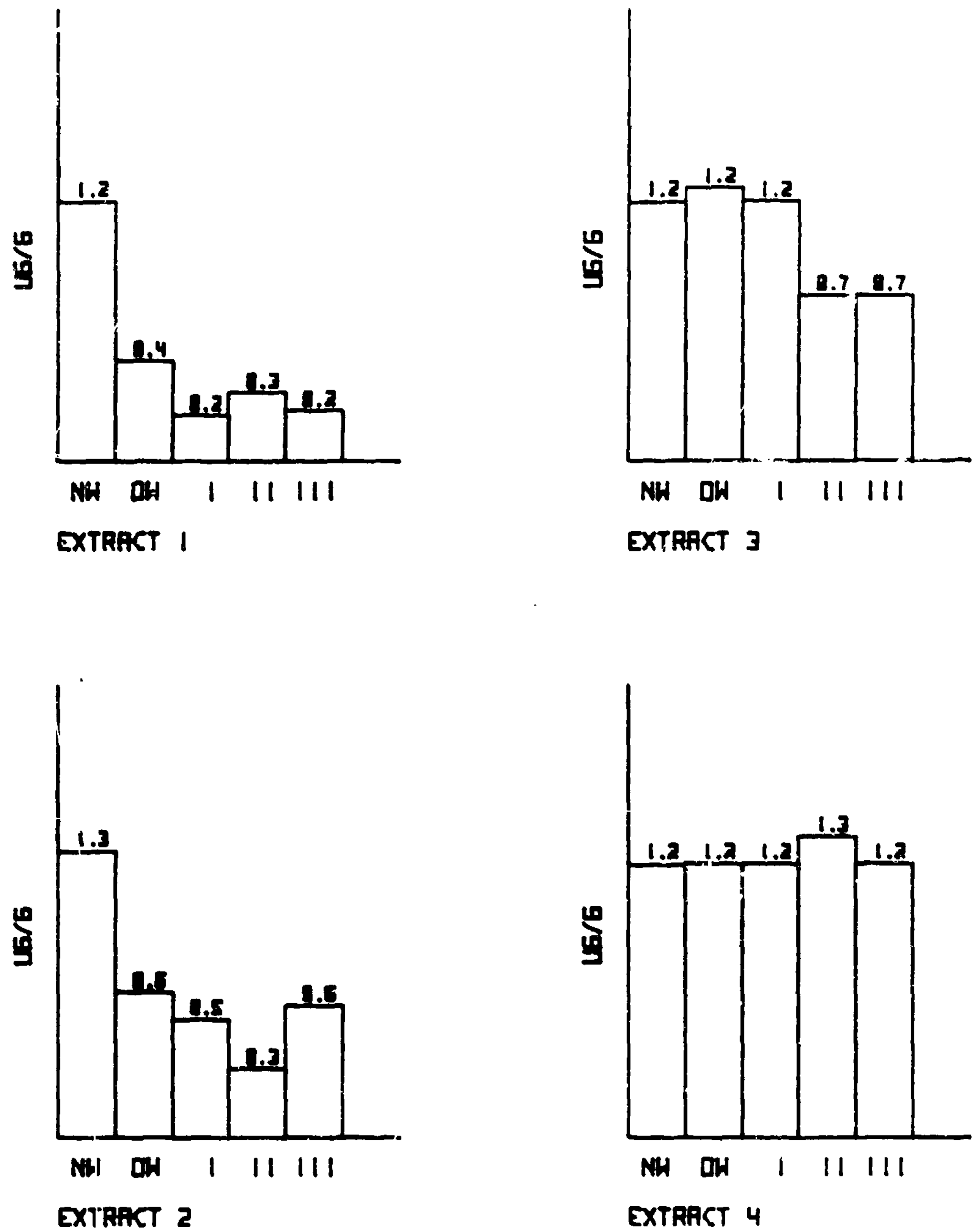

Figure D-11. Titanium Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

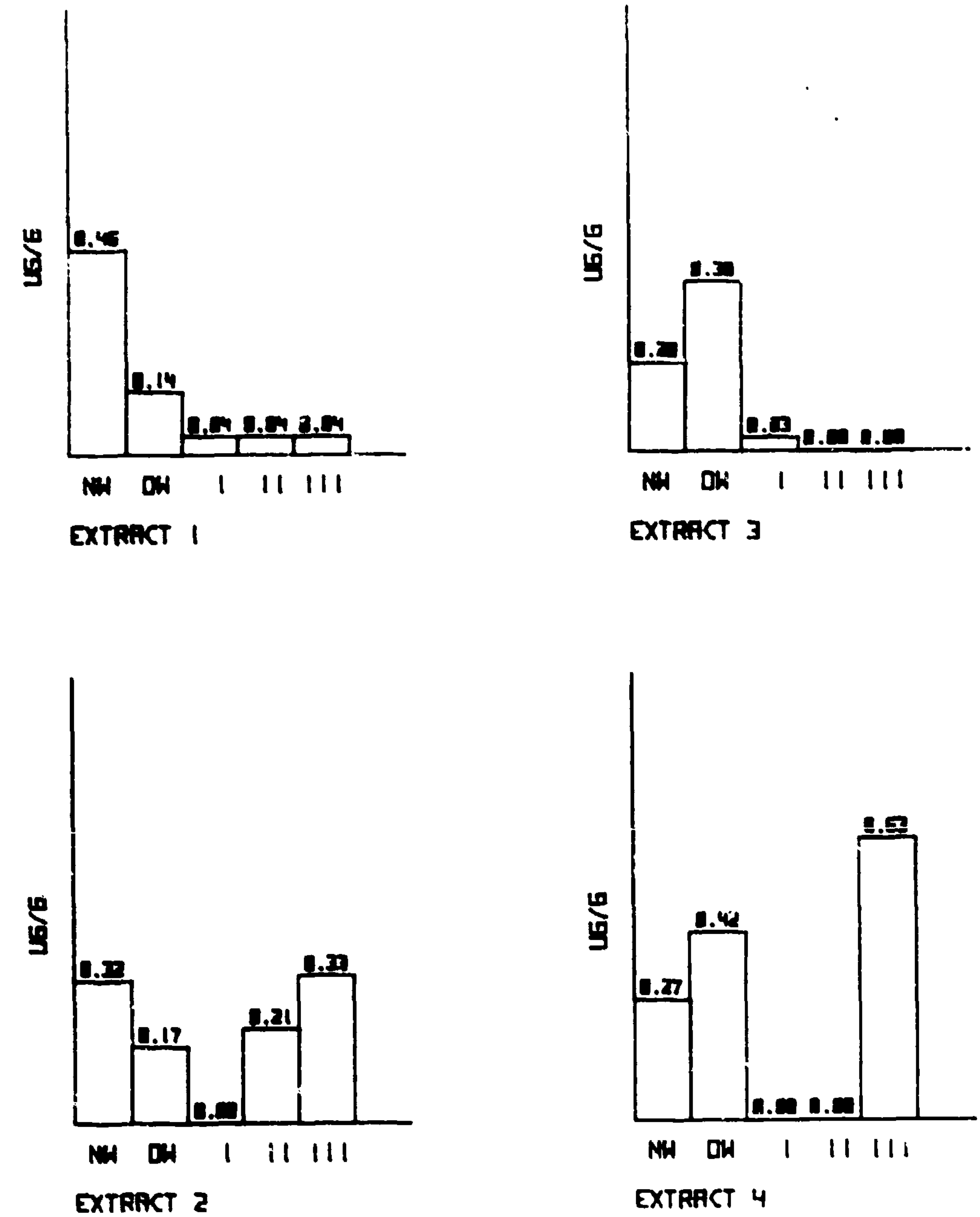

Figure D-12. Lead Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Chalmers Soil That Were Previously Extracted in Serial Batch Studies.

Table G-5. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE		AMT. PENETRATING		WT RETAINED	FRACTION RETAINED		EXTRACT	CONDUCTIV-
			µg/ml	µg/g	µg/ml	µg/g	µg/g	THIS	TOTAL	pH	ITY(µMHOS)
CHROMIUM	1	NW	.00	.00	.07	.14	-.14			7.5	200
		OW	.07	.14	.06	.12	.02	.14	.14	7.5	560
		I	.06	.12	.01	.02	.10	.83	.83	7.4	820
		II	.01	.02	.03	.06	-.04	-2.00	-2.00	7.1	6000
		III	.03	.06	.02	.04	.02	.33	.33	7.3	1000
	2	NW	.00	.00	.06	.18	-.18			7.4	330
		OW	.06	.18	.05	.15	.03	.17	.16	7.8	470
		I	.05	.15	.03	.09	.06	.40	.59	7.4	580
		II	.03	.09	.05	.15	-.06	-.67	-.91	6.8	1200
		III	.05	.15	.01	.03	.12	.80	.67	6.8	900
	3	NW	.00	.00	.03	.10	-.10			6.9	600
		OW	.03	.10	.05	.30	-.12	-.67	-.14	7.5	630
		I	.05	.30	.03	.18	.12	.40	.49	7.3	560
		II	.03	.18	.02	.12	.06	.33	-.14	7.4	500
		III	.02	.12	.02	.12	.00	.00	.42	7.1	710
	4	NW	.00	.00	.01	.12	-.12			7.6	1500
		OW	.01	.12	.03	.36	-.24	-2.00	-.50	7.5	1100
		I	.03	.36	.03	.36	.00	.00	.30	7.6	900
		II	.03	.36	.02	.24	.12	.33	.12	7.1	1000
		III	.02	.24	.01	.12	.12	.50	.46	7.2	860
TITANIUM	1	NW	.00	.00	.50	1.15	-1.15			7.6	200
		OW	.50	1.15	.22	.44	.71	.61	.61	7.6	560
		I	.22	.44	.10	.20	.24	.55	.55	7.4	820
		II	.10	.20	.20	.40	-.20	-1.00	-1.00	7.1	6000
		III	.20	.40	.10	.20	.20	.50	.50	7.3	1000
	2	NW	.00	.00	.42	1.27	-1.27			7.4	330
		OW	.42	1.27	.21	.64	.64	.50	.55	7.8	470
		I	.21	.64	.17	.52	.12	.19	.34	7.4	500
		II	.17	.52	.19	.58	-.06	-.12	-.40	6.8	1200
		III	.19	.58	.10	.30	.27	.47	.52	6.8	900
	3	NW	.00	.00	.19	1.15	-1.15			6.9	600
		OW	.19	1.15	.20	1.21	-.06	-.05	.36	7.5	630
		I	.20	1.21	.19	1.15	.06	.05	.19	7.3	560
		II	.19	1.15	.14	.85	.30	.26	-.02	7.4	500
		III	.14	.85	.10	.61	.24	.29	.42	7.1	710
	4	NW	.00	.00	.10	1.21	-1.21			7.6	1500
		OW	.10	1.21	.10	1.21	.00	.00	.27	7.5	1100
		I	.10	1.21	.12	1.45	-.24	-.20	.05	7.6	900
		II	.12	1.45	.10	1.21	.24	.17	.06	7.1	1000
		III	.10	1.21	.10	1.21	.00	.00	.26	7.2	860

Table D-5. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies. (Cont.)

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/ml	CHALLENGE mg/g	AMT. PENETRATING mg/ml	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (uMHOS)
LEAD	1	NW	.00	.00	.23	.46	-.46			7.6	290
		OW	.23	.46	.07	.14	.33	.71	.71	7.6	560
		I	.07	.14	-.02	-.03	.17	1.22	1.22	7.4	520
		II	-.02	-.03	.03	.06	-.09	2.04	2.04	7.1	6000
		III	.03	.06	.03	.06	-.01	-.16	-.15	7.3	1800
	2	NW	.00	.00	.11	.32	-.32			7.4	330
		OW	.11	.32	.06	.17	.15	.47	.61	7.8	470
		I	.06	.17	.00	.00	.17	1.00	1.10	7.4	580
		II	.00	.00	.09	.28	-.28	-919.74	12.22	6.8	1200
		III	.09	.28	.00	.01	.27	.98	.79	6.9	980
	3	NW	.00	.00	.03	.20	-.20			6.9	600
		OW	.03	.20	.06	.30	-.17	-.05	.31	7.5	630
		I	.06	.30	.03	.16	.22	.58	.01	7.3	560
		II	.03	.16	.02	.15	.01	.07	-2.77	7.4	580
		III	.02	.15	-.02	-.13	.28	1.07	1.12	7.1	710
	4	NW	.00	.00	.02	.27	-.27			7.6	1500
		OW	.02	.27	.03	.42	-.14	-.52	.13	7.5	1100
		I	.03	.42	.02	.20	.22	.52	.78	7.6	900
		II	.02	.20	-.03	-.40	.60	3.01	.75	7.1	1000
		III	-.03	-.40	.06	.75	-1.15	2.07	-7.62	7.2	860

[a]NW = new waste; OW = old waste; I,II,III designate three batches of soil, each of which were extracted using leachate from the batch above it in the sequence.

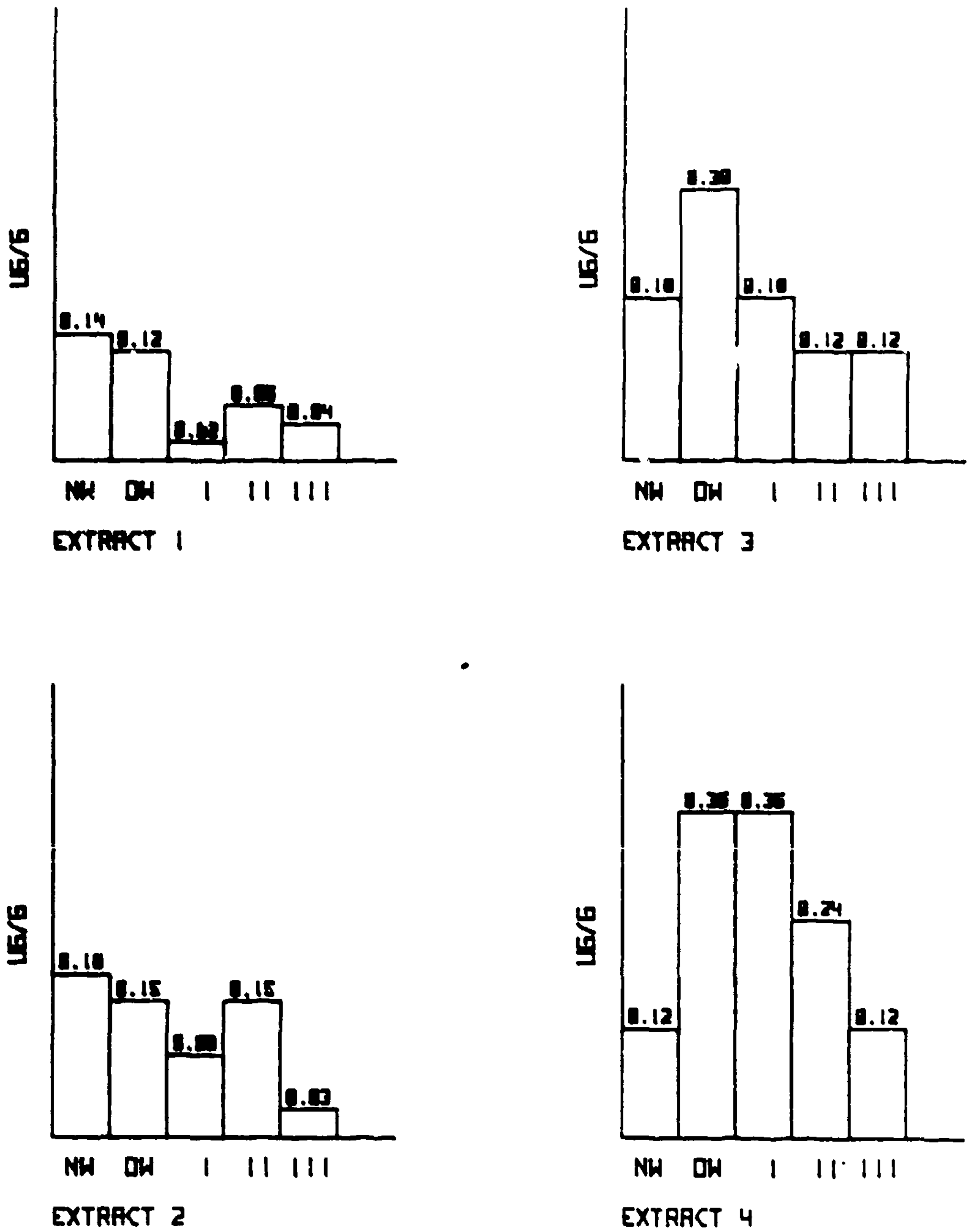

Figure D-13. Chromium Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

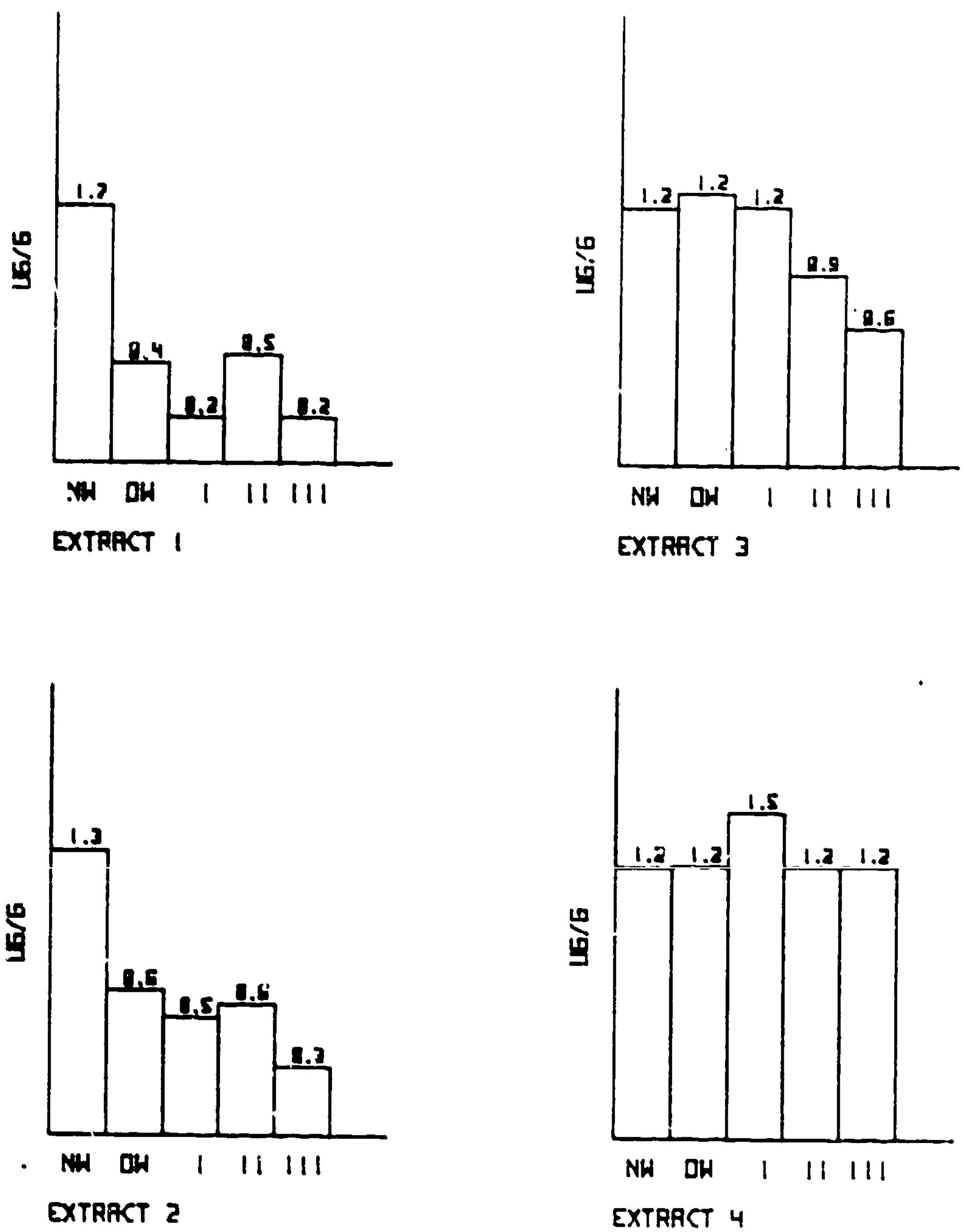

Figure D-14. Titanium Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Davidson Soil That Were Previously Extracted in Serial Batch Studies.

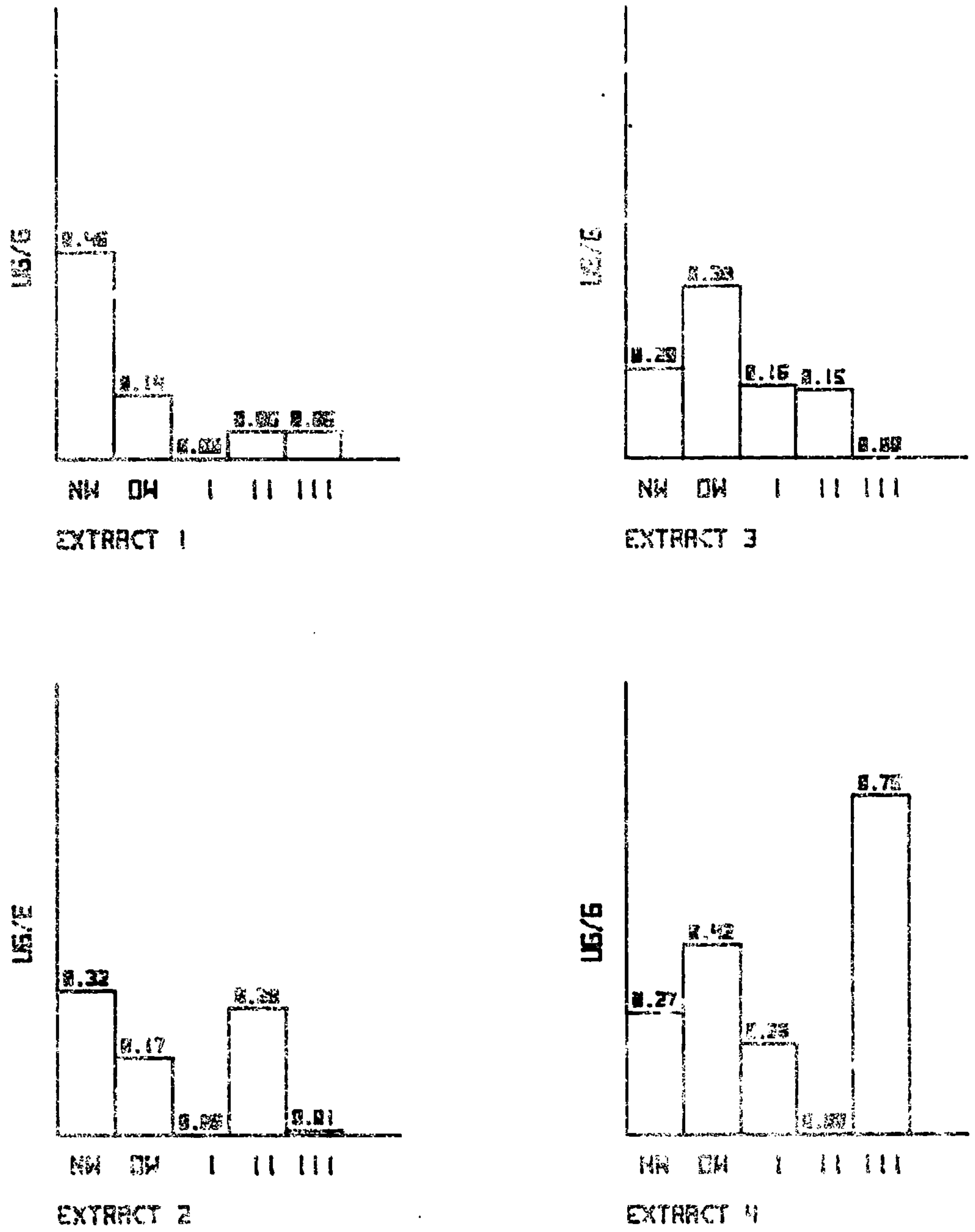

Figure D-15. Lead Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Davidson Soil that Were Previously Extracted in Serial Batch Studies.

Table D-6. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

METAL	EXTRACT	LAYER [a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/mL	AMT. PENETRATING mg/g	AMT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umHOS)
CHROMIUM	1	NW	.00	.00	.07	.14	-.14			7.6	200
		OW	.07	.14	.06	.12	.02	.14	.14	7.6	560
		I	.06	.12	[illegible]	.02	.10	.83	.83	7.2	990
		II	.01	.02	.01	.02	.00	.00	.00	6.9	1300
		III	.01	.02	.01	.02	.00	.00	.00	6.7	2700
	2	NW	.00	.00	.06	.18	-.18			7.4	330
		OW	.06	.18	.05	.15	.03	.17	.16	7.8	470
		I	.05	.15	.02	.06	.09	.60	.70	7.1	600
		II	.02	.06	.01	.03	.03	.50	.38	6.8	730
		III	.01	.03	.02	.06	-.03	-1.00	-.60	6.8	1500
	3	NW	.00	.00	.03	.18	-.18			6.9	600
		OW	.03	.18	.05	.30	-.12	-.67	-.14	7.5	630
		I	.05	.30	.05	.30	.00	.00	.33	7.2	560
		II	.05	.30	.02	.12	.18	.60	.55	7.0	620
		III	.02	.12	.01	.06	.06	.50	.18	7.2	760
	4	NW	.00	.00	.01	.12	-.12			7.6	1500
		OW	.01	.12	.03	.36	-.24	-2.00	-.50	7.5	1100
		I	.03	.36	.02	.24	.12	.33	.33	7.3	1000
		II	.02	.24	.02	.24	.00	.00	.34	7.2	920
		III	.02	.24	.01	.12	.12	.50	.37	7.3	800
TITANIUM	1	NW	.00	.00	.50	1.15	-1.15			7.6	200
		OW	.50	1.15	.22	.44	.71	.61	.61	7.6	560
		I	.22	.44	.10	.20	.24	.55	.55	7.2	990
		II	.10	.20	.10	.20	.00	.00	.00	6.9	1300
		III	.10	.20	.10	.20	.00	.00	.00	6.7	2700
	2	NW	.00	.00	.42	1.27	-1.27			7.4	330
		OW	.42	1.27	.21	.64	.64	.50	.55	7.8	470
		I	.21	.64	.16	.48	.15	.24	.36	7.1	600
		II	.16	.48	.10	.30	.18	.38	.26	6.8	730
		III	.10	.30	.10	.30	.00	.00	.00	6.8	1500
	3	NW	.00	.00	.17	1.15	-1.15			6.9	600
		OW	.17	1.15	.20	1.21	-.06	-.05	.36	7.5	630
		I	.20	1.21	.21	1.27	-.06	-.05	.15	7.2	560
		II	.21	1.27	.13	.79	.48	.38	.34	7.0	620
		III	.13	.79	.11	.67	.12	.15	.09	7.2	760
	4	NW	.00	.00	.10	1.21	-1.21			7.6	1500
		OW	.10	1.21	.10	1.21	.00	.00	.27	7.5	1100
		I	.10	1.21	.13	1.58	-.36	-.30	-.01	7.3	1000
		II	.13	1.58	.10	1.21	.36	.23	.29	7.2	920
		III	.10	1.21	.10	1.21	.00	.00	.05	7.3	800

Table D-6. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies. (Cont.)

METAL	EXTRACT	LATE[a]	CHALLENGE ug/ml	ug/g	AMT. PENETRATING ug/ml	ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	TOTAL	EXTRACT pH	CONDUCTIVITY(umHOS)
LEAD	1	NW	.00	.00	.23	.46	-.46			7.5	200
		OW	.23	.46	.07	.14	.33	.71	.71	7.6	560
		I	.07	.14	.00	.01	.13	.93	.93	7.2	990
		II	.00	.01	.01	.03	-.02	-2.22	-2.22	6.9	1300
		III	.01	.03	.04	.09	-.06	-1.99	-1.99	6.7	2700
	2	NW	.00	.00	.11	.32	-.32			7.4	330
		OW	.11	.32	.06	.17	.15	.47	.61	7.8	470
		I	.06	.17	-.00	-.00	.17	1.01	.97	7.1	600
		II	-.00	-.00	.05	.10	-.10	110.67	-14.46	6.8	730
		III	.05	.10	.02	.07	.03	.27	-.25	6.8	1500
	3	NW	.00	.00	.13	.20	-.20			6.9	600
		OW	.03	.20	.06	.30	-.17	-.05	.31	7.5	630
		I	.06	.30	.07	.42	-.04	-.12	.37	7.2	560
		II	.07	.42	-.02	-.10	.52	1.23	.93	7.0	620
		III	-.02	-.10	-.04	-.23	.13	-1.34	3.00	7.2	760
	4	NW	.02	.00	.02	.27	-.27			7.6	1500
		OW	.02	.27	.03	.42	-.14	-.52	.13	7.5	1100
		I	.03	.42	.01	.10	.32	.76	.52	7.3	1090
		II	.01	.10	-.04	-.43	.53	5.25	1.75	7.2	920
		III	-.04	-.43	.01	.09	-.51	1.29	1.05	7.3	800

[a] NW = new waste; OW = old waste; I,II,III designate three batches of soil, each of which were extracted using leachate from the batch above it in the sequence.

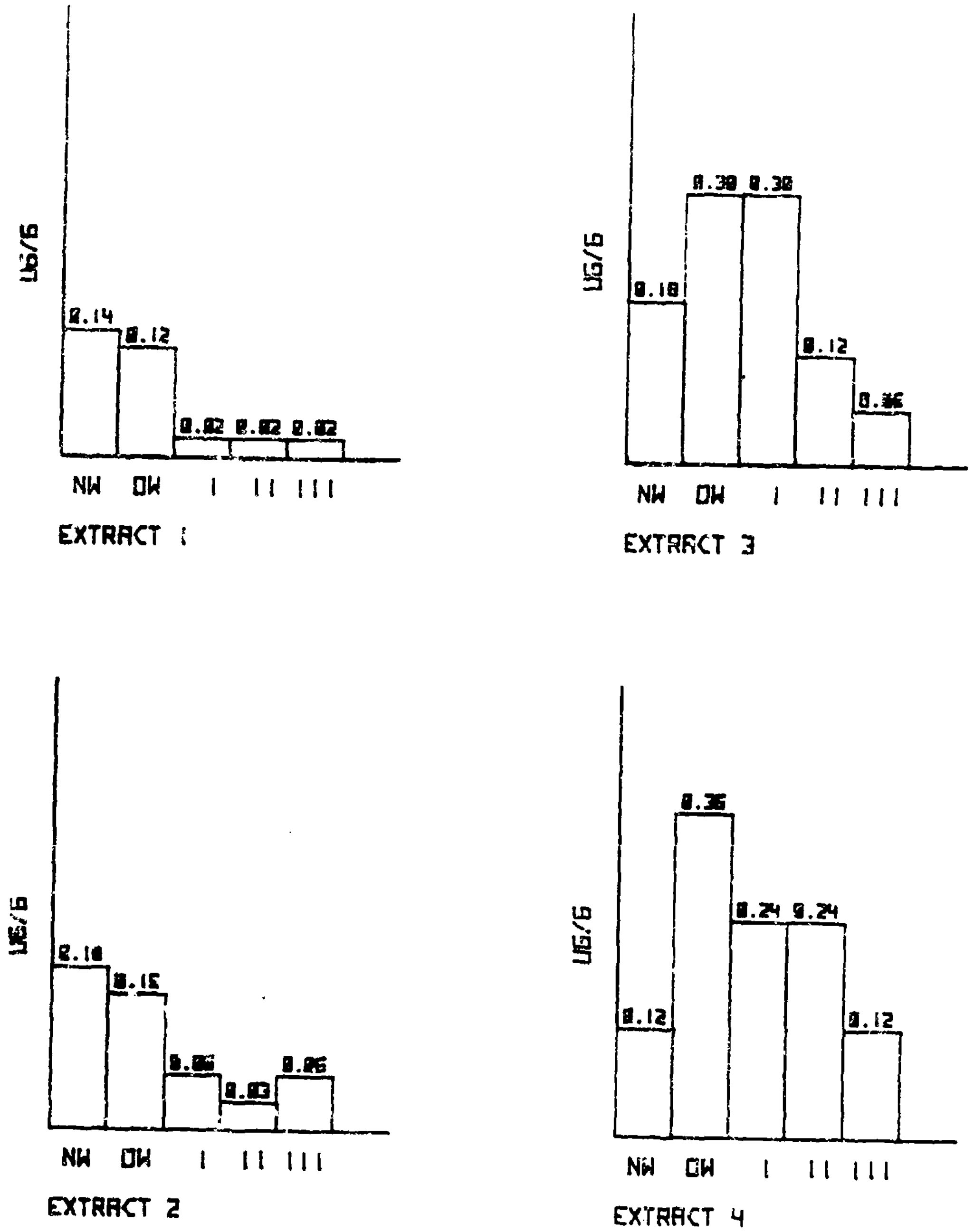

Figure D-16. Chromium Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

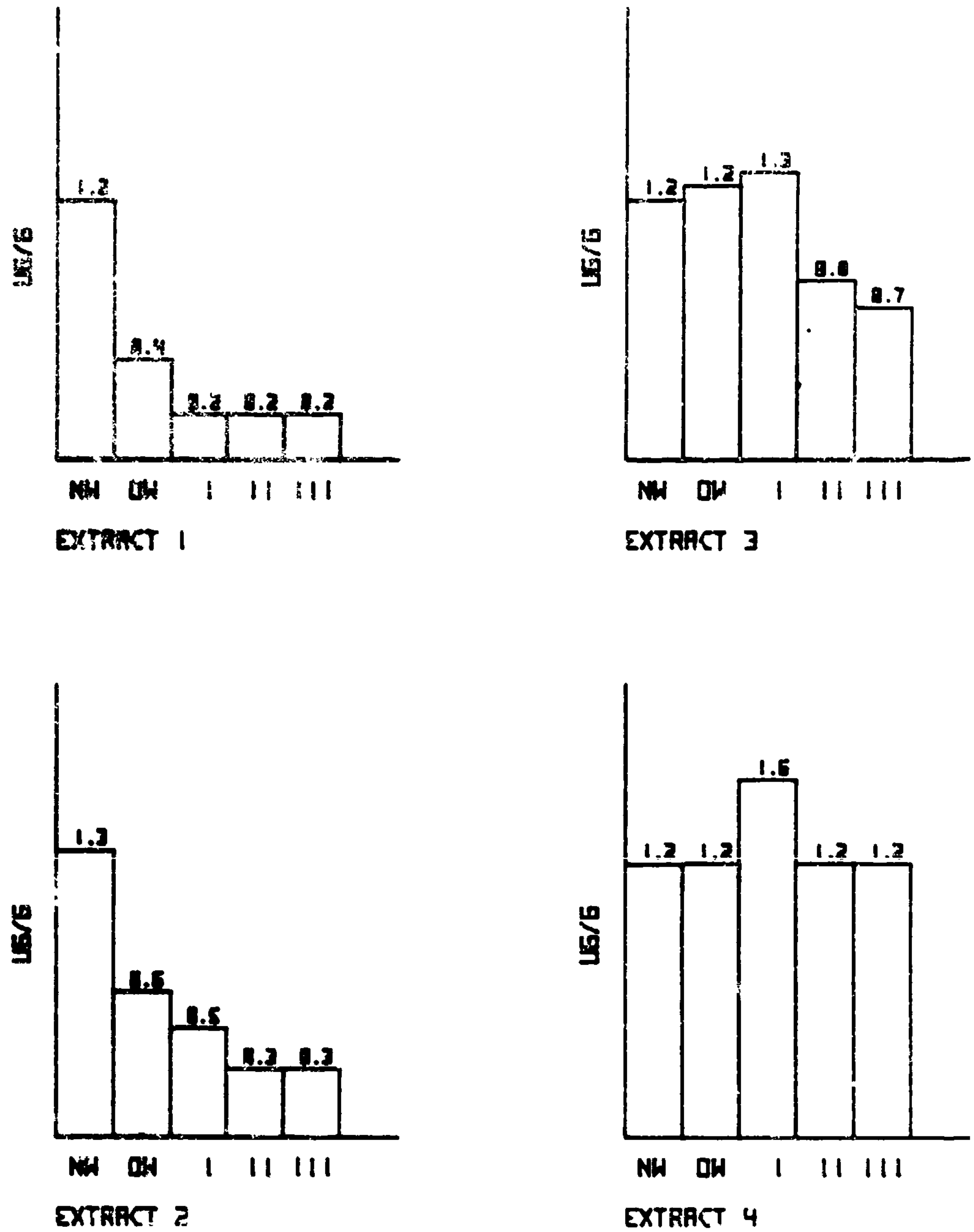

Figure D-17. Titanium Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

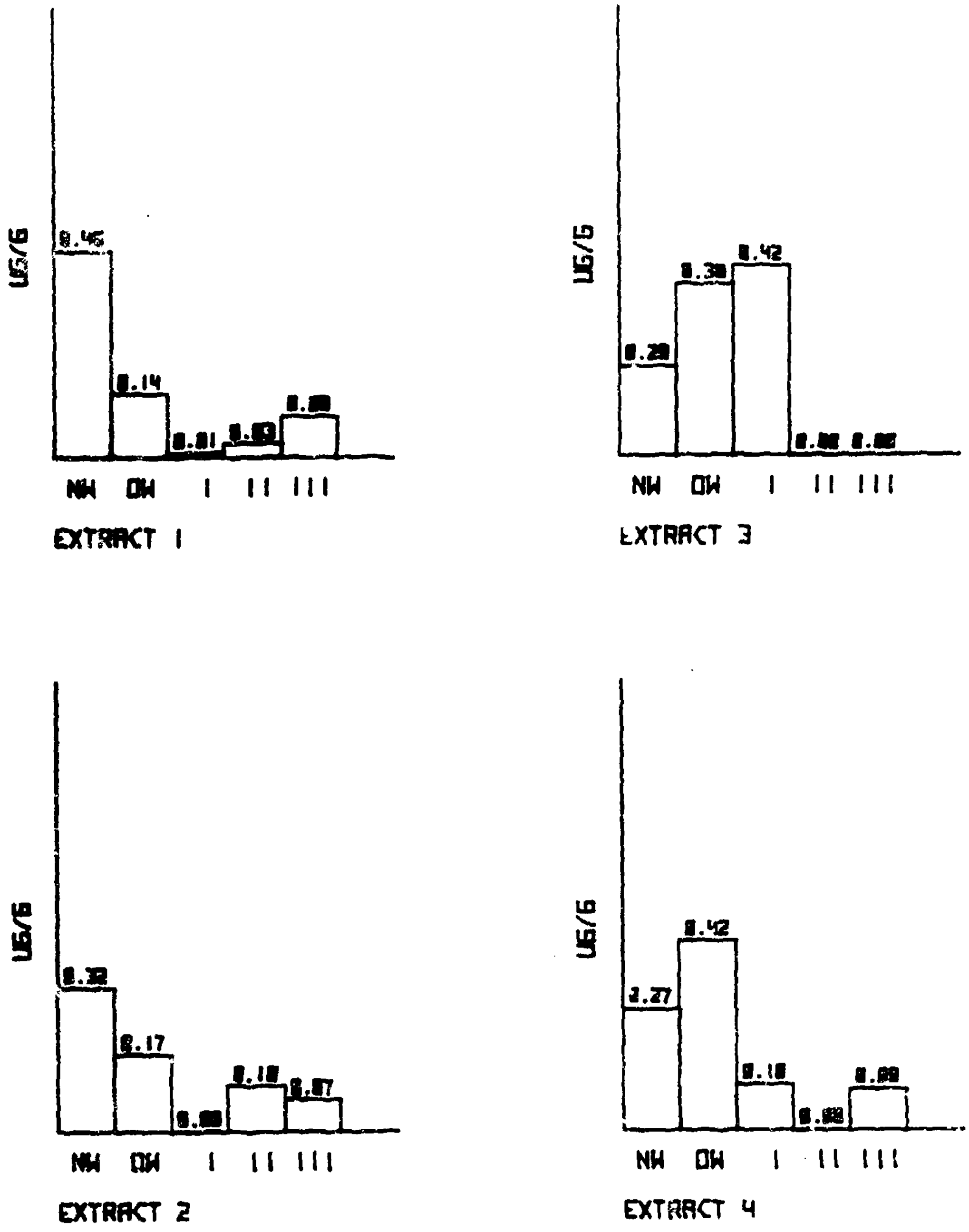

Figure D-18. Lead Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Titanium Dioxide Pigment Waste and Nicholson Soil That Were Previously Extracted in Serial Batch Studies.

Table D-7. Selected Metals Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Chalmers Soil Previously Exposed to Zinc-Carbon Battery Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/mL	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhos)
LEAD	1	NW	.00	.00	.05	.10	-.10			7.4	70
		I	.05	.10	.04	.08	.02	.21	.21	7.1	23
	2	NW	.00	.00	.09	.26	-.26			7.6	66
		I	.09	.26	.07	.20	.05	.21	.21	7.2	47
	3	NW	.00	.00	.10	.57	-.57			7.9	500
		I	.10	.57	.09	.55	.02	.03	.10	7.4	150
	4	NW	.00	.00	.09	1.14	-1.14			7.6	600
		I	.09	1.14	.39	1.13	.00	.00	.05	7.7	540
CADMIUM	1	NW	.00	.00	4.14	8.28	-8.28			7.4	70
		I	4.14	8.28	4.23	8.46	-.18	-.02	-.02	7.1	23
	2	NW	.00	.00	1.14	3.42	-3.42			7.6	66
		I	1.14	3.42	1.29	3.88	-.45	-.13	-.05	7.2	47
	3	NW	.00	.00	.12	.73	-.73			7.9	500
		I	.12	.73	.08	.48	.24	.33	-.03	7.4	150
	4	NW	.00	.00	.08	.97	-.97			7.6	600
		I	.08	.97	.01	.12	.85	.88	.03	7.7	540
ZINC	1	NW	.00	.00	387.84	775.68	-775.68			7.4	70
		I	387.84	775.68	97.69	199.37	576.31	.74	.74	7.1	23
	2	NW	.00	.00	54.74	164.23	-164.23			7.6	66
		I	54.74	164.23	33.83	101.51	62.72	.38	.60	7.2	47
	3	NW	.00	.00	6.87	41.21	-41.21			7.9	500
		I	6.87	41.21	3.68	22.06	19.15	.46	.67	7.4	150
	4	NW	.00	.00	3.10	37.21	-37.21			7.6	600
		I	3.10	37.21	.46	5.58	31.63	.05	.68	7.7	540

[a]NW = new waste; I = batch of soil.

Table D-8. Selected Metals Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Davidson Soil Previously Exposed to Zinc-Carbon Battery Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE µg/mL	CHALLENGE µg/g	AMT. PENETRATING µg/mL	AMT. PENETRATING µg/g	WT RETAINED µg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (µMHOS)
LEAD	1	NW	.00	.00	.05	.10	-.10			7.4	70
		I	.05	.10	.05	.10	.01	.06	.06	6.9	22
	2	NW	.00	.00	.09	.26	-.26			7.6	66
		I	.09	.26	.07	.21	.04	.17	.14	7.1	52
	3	NW	.00	.00	.10	.57	-.57			7.9	500
		I	.10	.57	.09	.54	.03	.06	.09	7.2	140
	4	NW	.00	.06	.09	1.14	-1.14			7.6	600
		I	.09	1.14	.10	1.15	-.01	-.01	.03	7.4	460
CADMIUM	1	NW	.00	.00	4.14	8.28	-8.28			7.4	70
		I	4.14	8.28	3.92	7.84	.44	.05	.05	6.9	22
	2	NW	.00	.00	1.14	3.42	-3.42			7.6	66
		I	1.14	3.42	1.23	3.70	-.27	-.08	.01	7.1	52
	3	NW	.00	.00	.12	.73	-.73			7.9	500
		I	.12	.73	.28	1.70	-.97	-1.33	-.06	7.2	140
	4	NW	.00	.00	.08	.97	-.97			7.6	600
		I	.08	.97	.02	.24	.73	.75	-.01	7.4	460
ZINC	1	NW	.00	.00	307.84	775.68	-775.68			7.4	70
		I	307.84	775.68	98.07	196.14	579.54	.75	.75	6.9	22
	2	NW	.00	.00	54.74	164.23	-164.23			7.6	66
		I	54.74	164.23	21.61	64.84	99.38	.61	.72	7.1	52
	3	NW	.00	.00	6.87	41.21	-41.21			7.9	500
		I	6.87	41.21	6.77	40.60	.61	.01	.69	7.2	140
	4	NW	.00	.00	3.10	37.21	-37.21			7.6	600
		I	3.10	37.21	1.04	12.48	24.73	.66	.69	7.4	460

[a]NW = new waste; I = batch of soil.

Table D-9. Selected Metals Extracted by New Zinc-Carbon Battery Waste Leachate Placed on Chalmers Soil Previously Exposed to Zinc-Carbon Battery Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhos)
LEAD	1	NW	.00	.00	.05	.10	-.10			7.4	70
		I	.05	.10	.05	.09	.01	.13	.13	6.9	24
	2	NW	.00	.00	.09	.26	-.26			7.6	66
		I	.09	.26	.07	.22	.04	.16	.15	7.1	52
	3	NW	.00	.00	.10	.57	-.57			7.9	505
		I	.10	.57	.09	.54	.03	.04	.10	7.5	150
	4	NW	.00	.00	.09	1.14	-1.14			7.6	600
		I	.09	1.14	.09	1.14	-.00	-.00	.04	7.5	410
CADMIUM	1	NW	.00	.00	4.14	8.28	-8.28			7.4	70
		I	4.14	8.28	4.05	8.10	.18	.02	.02	6.9	24
	2	NW	.00	.00	1.14	3.42	-3.42			7.6	66
		I	1.14	3.42	1.29	3.88	-.45	-.13	-.02	7.1	58
	3	NW	.00	.00	.12	.73	-.73			7.9	500
		I	.12	.73	.14	.85	-.12	-.17	-.03	7.5	150
	4	NW	.00	.00	.00	.97	-.97			7.6	600
		I	.00	.97	.02	.24	.73	.75	.02	7.5	410
ZINC	1	NW	.00	.00	387.84	775.68	-775.68			7.4	70
		I	387.84	775.68	99.99	199.98	575.70	.74	.74	6.9	24
	2	NW	.00	.00	94.74	164.23	-164.23			7.5	66
		I	94.74	164.23	25.87	80.60	83.63	.51	.70	7.1	58
	3	NW	.00	.00	6.87	41.21	-41.21			7.9	500
		I	6.87	41.21	3.71	22.24	18.97	.46	.69	7.5	150
	4	NW	.00	.00	3.16	37.21	-37.21			7.6	600
		I	3.16	37.21	.73	8.73	28.48	.77	.69	7.5	410

[a]NW = new waste; I = batch of soil.

Table D-10. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Chalmers Soil Previously Exposed to Titanium Dioxide Pigment Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE ug/mL	CHALLENGE ug/g	AMT. PENETRATING ug/mL	AMT. PENETRATING ug/g	WT RETAINED ug/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhos)
CHROMIUM	1	NW	.06	.00	.07	.14	-.14			7.6	200
		I	.07	.14	.06	.12	.02	.14	.14	6.7	240
	2	NW	.00	.09	.06	.18	-.18			7.4	330
		I	.06	.18	.05	.15	.03	.17	.16	7.0	410
	3	NW	.00	.00	.03	.18	-.18			6.9	600
		I	.03	.18	.02	.12	.06	.33	.22	7.0	590
	4	NW	.00	.06	.01	.12	-.12			7.6	1500
		I	.01	.12	.01	.12	.00	.00	.18	7.4	1100
TITANIUM	1	NW	.00	.00	.58	1.15	-1.15			7.6	200
		I	.58	1.15	.43	.8[illegible]	.28	.25	.25	6.7	240
	2	NW	.00	.00	.42	1.27	-1.27			7.4	330
		I	.42	1.27	.33	1.00	.27	.21	.23	7.0	410
	3	NW	.09	.00	.19	1.15	-1.15			6.9	600
		I	.19	1.15	.1[illegible]	.91	.24	.21	.22	7.0	590
	4	NW	.00	.00	.10	1.21	-1.21			7.6	1500
		I	.10	1.21	.10	1.21	.00	.00	.17	7.4	1100
[illegible]	1	NW	.00	.00	.23	.46	-.46			7.6	200
		I	.23	.46	.13	.27	.20	.42	.42	6.7	240
	2	NW	.00	.00	.11	.32	-.32			7.4	330
		I	.11	.32	.11	.32	-.00	-.02	.24	7.0	410
	3	NW	.00	.[illegible]	.0[illegible]	.20	-.20			6.9	600
		I	.03	.20	-.0[illegible]	-.06	.27	1.32	.47	7.0	590
	4	NW	.0[illegible]	.00	.02	.27	-.27			7.6	1500
		I	.02	.27	-.01	-.07	.34	1.25	.64	7.4	1100

[a]NW = new waste; I = batch of soil.

Table D-11. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Davidson Soil Previously Exposed to Titanium Dioxide Pigment Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/ml	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhos)
CHROMIUM	1	NW	.00	.00	.07	.14	-.14			7.6	200
		I	.07	.14	.05	.10	.04	.29	.29	6.9	230
	2	NW	.00	.00	.06	.10	-.10			7.4	330
		I	.06	.10	.04	.12	.06	.33	.31	7.0	410
	3	NW	.00	.00	.05	.10	-.10			6.9	600
		I	.03	.10	.02	.12	.06	.33	.32	7.2	540
	4	NW	.00	.00	.01	.12	-.12			7.6	1500
		I	.01	.12	.02	.24	-.12	-1.00	.06	7.1	1450
TITANIUM	1	NW	.00	.00	.58	1.15	-1.15			7.6	200
		I	.58	1.15	.43	.87	.28	.25	.25	6.9	230
	2	NW	.00	.00	.42	1.27	-1.27			7.4	330
		I	.42	1.27	.34	1.03	.24	.19	.22	7.0	410
	3	NW	.00	.00	.19	1.15	-1.15			6.9	600
		I	.19	1.15	.18	1.09	.06	.05	.16	7.2	540
	4	NW	.00	.00	.10	1.21	-1.21			7.6	1500
		I	.10	1.21	.11	1.33	-.12	-.10	.10	7.1	1450
LEAD	1	NW	.00	.00	.23	.46	-.46			7.6	200
		I	.23	.46	.15	.31	.16	.34	.34	6.9	230
	2	NW	.00	.00	.11	.32	-.32			7.4	330
		I	.11	.32	.13	.39	-.07	-.21	.12	7.0	410
	3	NW	.00	.00	.03	.20	-.20			6.9	600
		I	.03	.20	.03	.16	.05	.23	.14	7.2	540
	4	NW	.00	.00	.02	.27	-.27			7.6	1500
		I	.02	.27	.00	.02	.26	.94	.31	7.1	1450

[a]NW = new waste; I = batch of soil.

Table D-12. Selected Metals Extracted by New Titanium Dioxide Pigment Production Waste Leachate Placed on Nicholson Soil Previously Exposed to Titanium Dioxide Pigment Waste Leachate in Soil Capacity Studies.

METAL	EXTRACT	LAYER[a]	CHALLENGE mg/mL	CHALLENGE mg/g	AMT. PENETRATING mg/mL	AMT. PENETRATING mg/g	WT RETAINED mg/g	FRACTION RETAINED THIS	FRACTION RETAINED TOTAL	EXTRACT pH	CONDUCTIVITY (umhos)
CHROMIUM	1	NW	.00	.00	.07	.14	-.14			7.5	200
		I	.07	.14	.06	.12	.02	.14	.14	6.1	250
	2	NW	.00	.00	.06	.18	-.18			7.4	330
		I	.06	.18	.04	.12	.06	.33	.25	5.8	380
	3	NW	.00	.00	.03	.10	-.10			6.9	600
		I	.03	.10	.02	.12	.06	.33	.28	6.5	540
	4	NW	.00	.00	.01	.12	-.12			7.6	1500
		I	.01	.12	.01	.12	.00	.00	.23	7.0	1300
TITANIUM	1	NW	.00	.00	.58	1.15	-1.15			7.6	200
		I	.58	1.15	.52	1.03	.12	.11	.11	6.1	250
	2	NW	.00	.00	.42	1.27	-1.27			7.4	330
		I	.42	1.27	.27	.82	.45	.36	.24	6.8	380
	3	NW	.00	.00	.19	1.15	-1.15			6.9	600
		I	.19	1.15	.14	.85	.30	.26	.25	6.6	540
	4	NW	.00	.00	.10	1.21	-1.21			7.6	1500
		I	.10	1.21	.10	1.21	.00	.00	.18	7.0	1300
LEAD	1	NW	.00	.00	.23	.46	-.46			7.6	200
		I	.23	.46	.09	.19	.27	.59	.59	6.1	250
	2	NW	.00	.00	.11	32	-.32			7.4	330
		I	.11	.32	.10	.29	.03	.09	.39	6.8	380
	3	NW	.00	.00	.03	.20	-.20			6.9	600
		I	.03	.20	-.03	-.20	.40	1.99	.71	6.6	540
	4	NW	.00	.00	.02	.27	-.27			7.6	1500
		I	.02	.27	.02	.19	.08	.29	.62	7.0	1300

[a]NW = new waste; I = batch of soil.

APPENDIX E

RELATING BATCH AND COLUMN PROCEDURES TO THE FIELD

AN INCREMENTAL INTERPRETATION OF LEACHING

If a bed of waste is visualized as being divided into thickness increments, and if the leachant is divided into volume increments, a thickness-by-elution volume array can be constructed that will allow depicting the progress of leaching. Such a diagram helps show the extent to which batch and column waste leaching procedures simulate the field situation.

A thickness increment can be taken to be one batch or the length of a column, and a volume increment can be one batch extraction, one day's leaching in a column, or one bed volume. Different cross-hatching patterns and the differing distribution coefficients and concentrations in Figure E-1 emphasize that the passage of leachate changes the waste and/or soil and that the differing waste and soil increments have different effects on the leachate. This cascading interaction causes the composition of every increment of volume to differ from each of the others.

WHAT IS SIMULATED BY COLUMN PROCEDURES

The length of the column is the thickness of the increment that is evaluated in a basic column procedure. An average concentration and distribution coefficient is obtained for the volume that is mixed together in the sampling bottle. Figure E-2 shows that a changed increment of waste or soil greets the next increment of leachant that flows into the column. A series of n volume increments will give a horizontal set of such pictures. No information is obtained about what happens at greater depths. Extrapolation cannot be presumed to be possible. A stacked series of columns would be required to obtain data concerning the bed and the leachate deeper in the waste or soil.

WHAT IS SIMULATED BY BATCH PROCESSES

A single extraction batch test can be represented by the left-hand part of Figure E-3. A serial extraction batch test would give a horizontal set of pictures similar to the column techniques. The graded serial batch extraction procedure employed in this report allows maintaining the same liquid-to-solid ratio while investigating greater bed depths. This procedure can also be depicted as in Figure E-4.

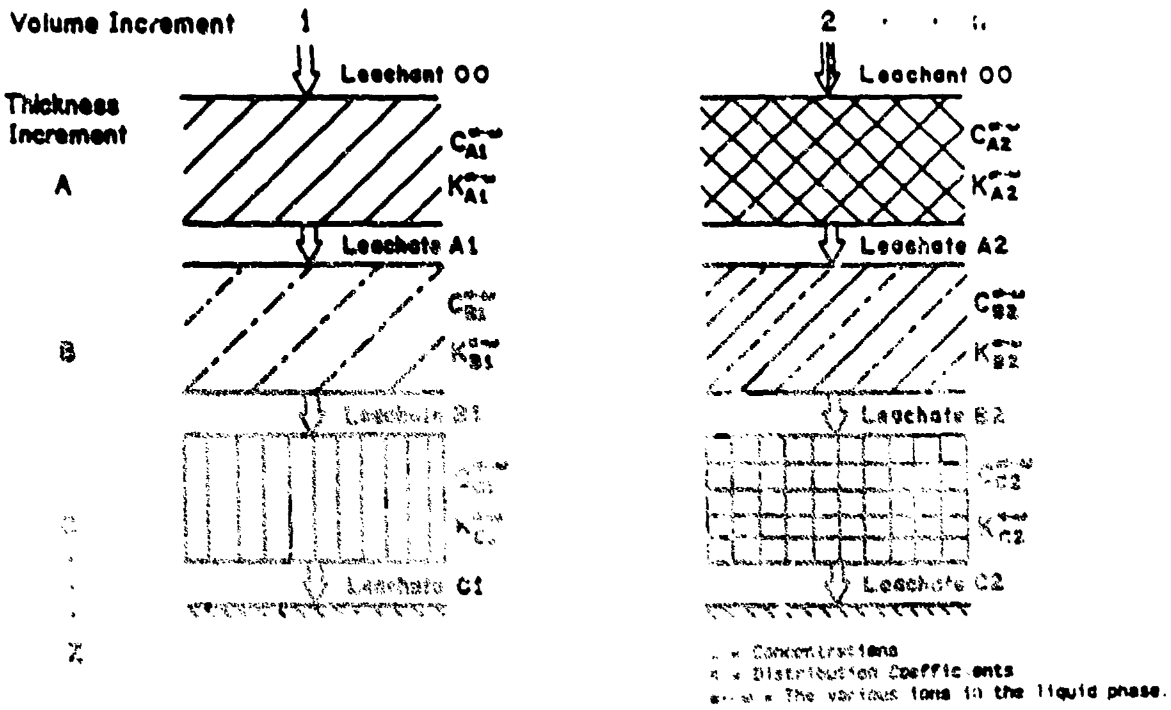

Figure E-1. Each Increment of Leachate and of Waste or Soil Become Different from Every Other Increment.

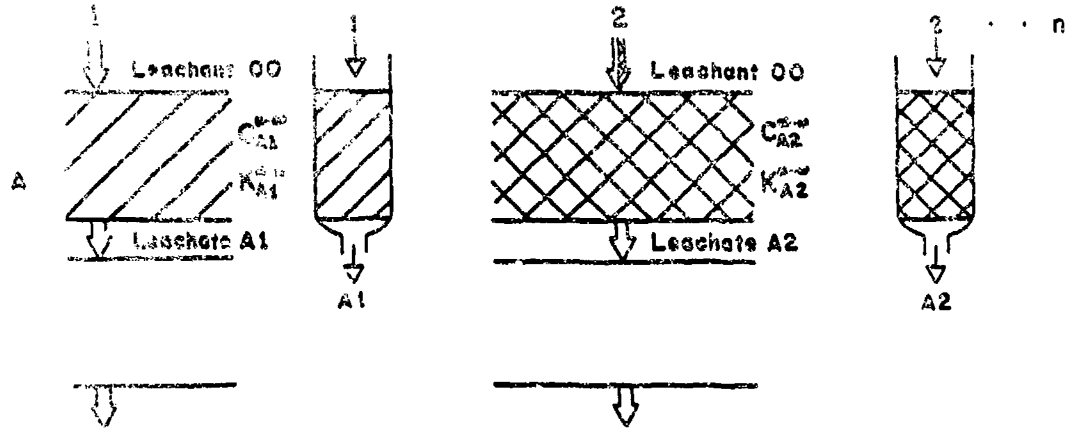

Figure E-2. A Column Procedure investigates One Increment of Depth.

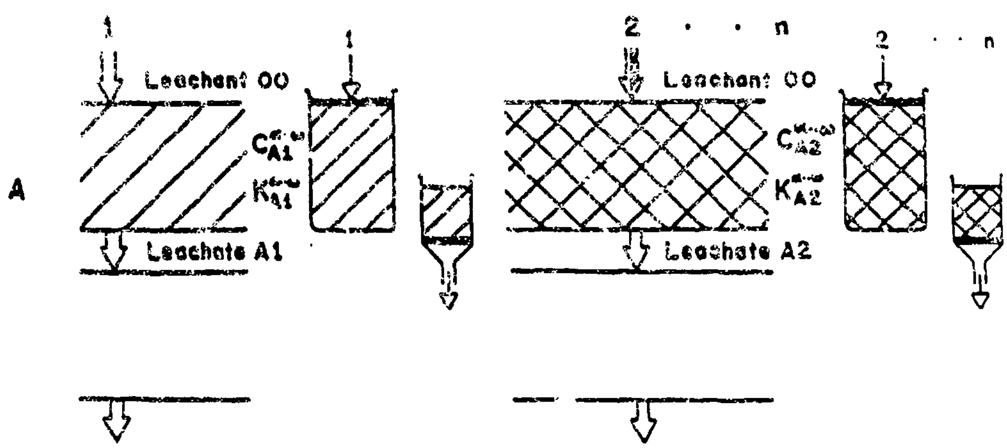

Figure E-3. Single or Sequential Batch Procedures Normally Investigate One Increment of Depth.

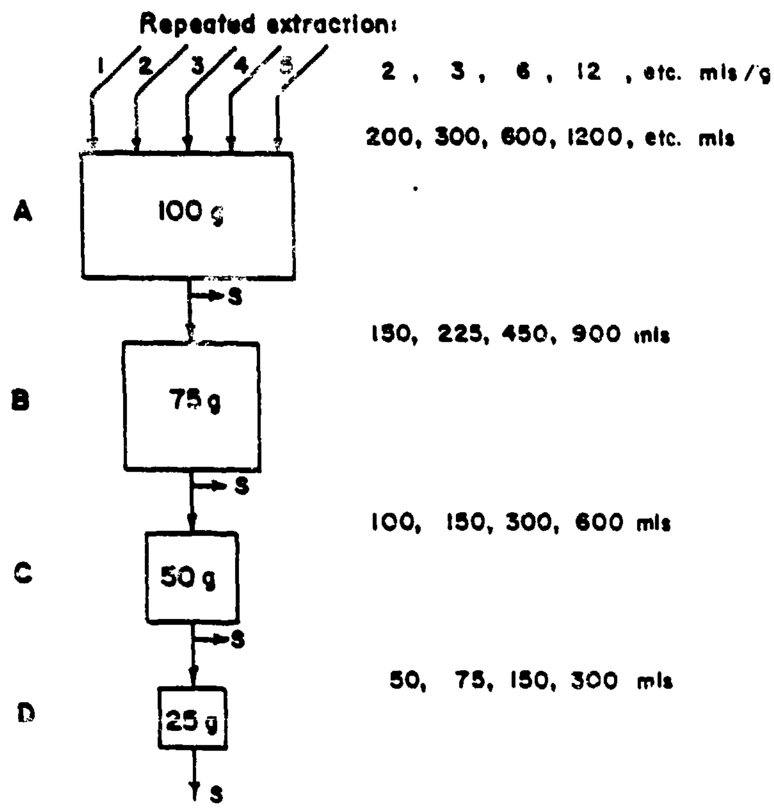

Figure E-4. A Graded Serial Batch Extraction Procedure That Maintains a Constant Liquid-to-Solid Ratio at Increasing Depths.

COMPARING LABORATORY PROCEDURES WITH THE FIELD

Procedures employing Soxhlet extractions; extractions employing excessive liquid-to-solid ratios, excessive contact times, or vigorous mixing that breaks up aggregates; operating columns with accelerated flow or with up and then down flow; using simplified artificial leachants or buffered leachants -- all these can yield distribution coefficients and concentrations that do not represent any location in the field.

When a sample is taken in the field and brought to the laboratory for the purpose of running validation tests on batch or column procedures, the already partially-leached sample of waste should not be extracted by water, because the result will not represent any real field situation and should not be used for comparisons. A study of Figure E-5 will show why the waste sample should be leached with leachate obtained at that same depth.

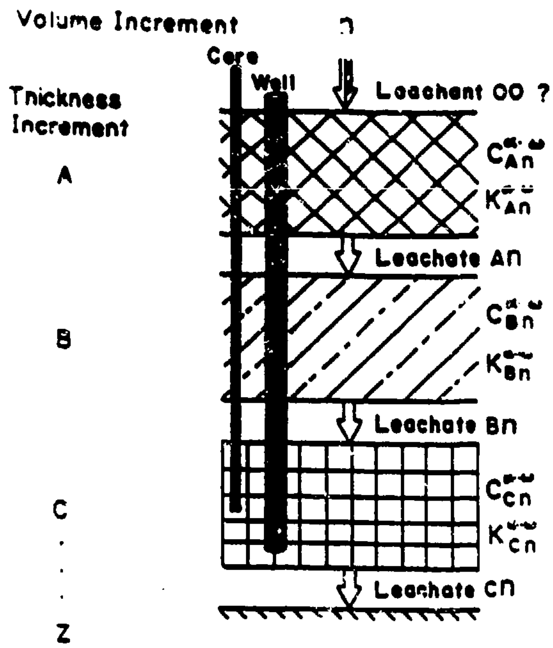

Figure E-5. Take Samples of Waste and Leachate from the Same Increment for Valid Comparisons.

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